LITANI WATER QUALITY MANAGEMENT PROJECT

Canal 900 Algae Control: Testing and Validation

September 2005

Litani Basin Management Advisory Services (BAMAS)

Bureau for Asia and the Near East
U.S. Agency for International Development

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REPORT PREPARATION

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Cover Photo: Application of Copper Sulfate to Canal Near K2 Pump Station

1. Background

Water in the 900 Canal is subject to algae proliferation during the summer as a result of several factors including high levels of nitrogen (N) and phosphorous (P) from untreated domestic wastewater and agricultural runoff, long daylight duration, high temperature, low flow velocity, and long watercourse retention time. Algae have caused water flow retardation, clogging of irrigation drippers, foul odors, and mosquitoes resulting in complaints from farmers and inhabitant in the area served by the canal. Under these conditions, farmers have been reluctant to subscribe to the canal water deliveries. As a result, the canal is currently operating at around 30% of its capacity, serving 1,900 hectares out of the originally planned 7,000 hectares of irrigated land. A large percentage of the farmers use more expansive groundwater that is being gradually over-exploited.

Based on the above and on LRA’s urgency to solve the algae proliferation issue, BAMAS project made algae control as one of the project priorities. It carried out an algae control program for Canal 900 that includes:

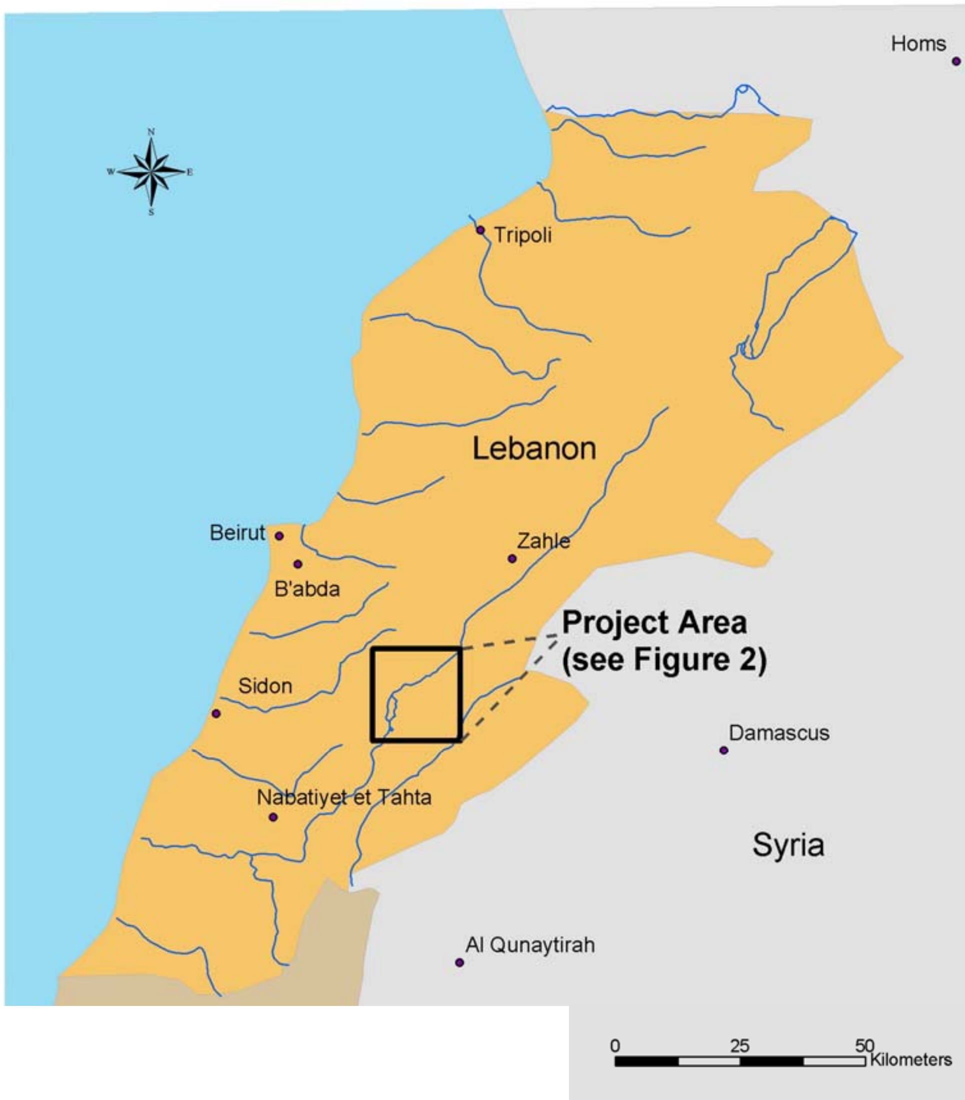
- Evaluation of previous studies;
- Identification, testing, and validation of algae control solution (s); and
- Preparation of a scope of work for implementation of the recommended solution (s) by LRA.

This report presents a detailed description of the activities, results, and recommendation of this program.

2. Canal Characteristics

The canal is operated by the Litani River Authority and is located in south central portion of Lebanon’s Bekaa Valley. Refer to **Figures 1 and 2**.

FIGURE 1. Project Vicinity Map



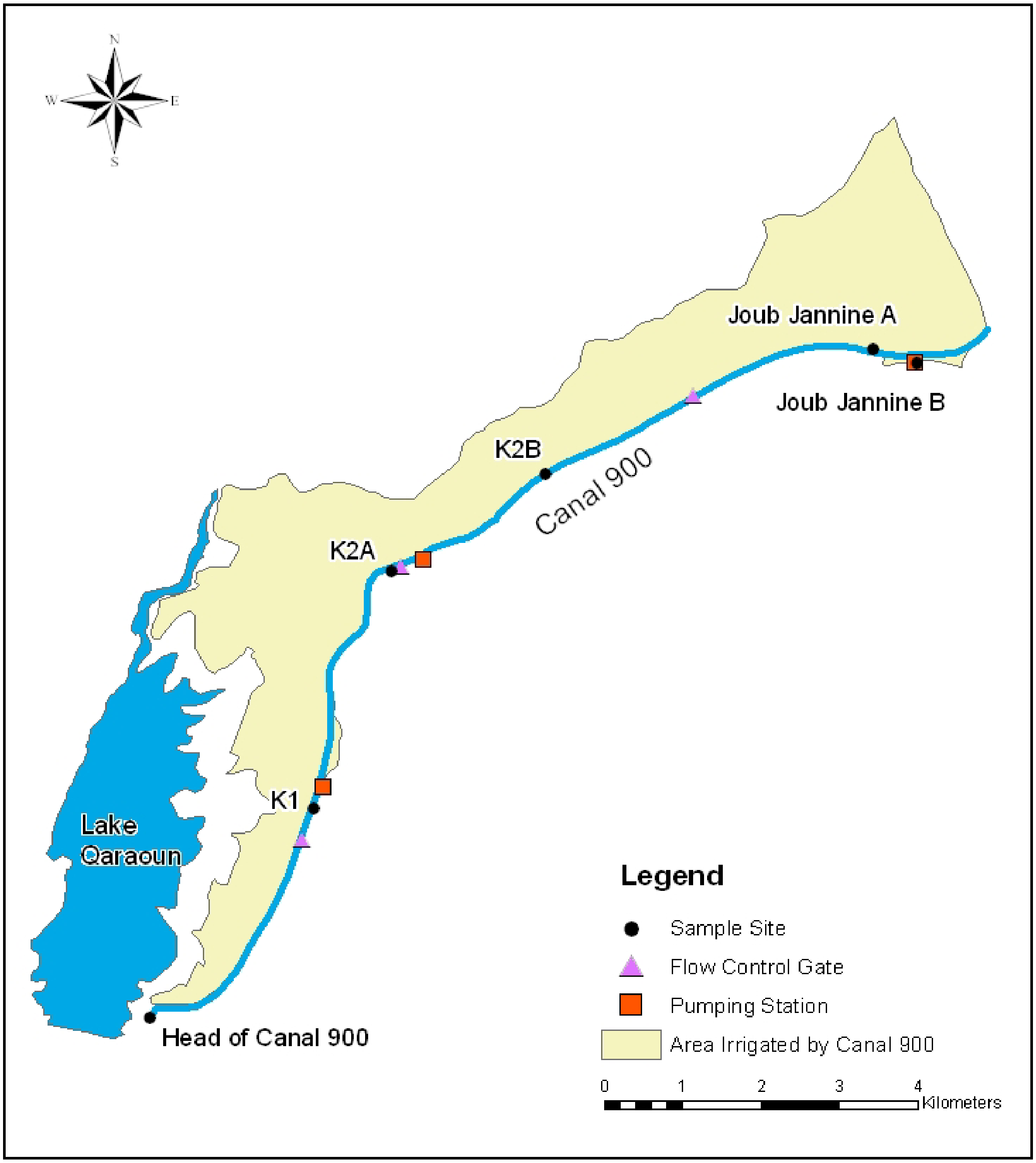


Figure 2. Project Location Map

Canal 900 an open, combination rectangular and trapezoidal, concrete-lined channel of approximately 18.5 km. It is divided roughly into 4 equal reaches of average slope of 0.2 % and delivers irrigation water from Lake Karaoun to approximately 1900 Hectares (Ha). Refer to **Figures 3 and 4**.

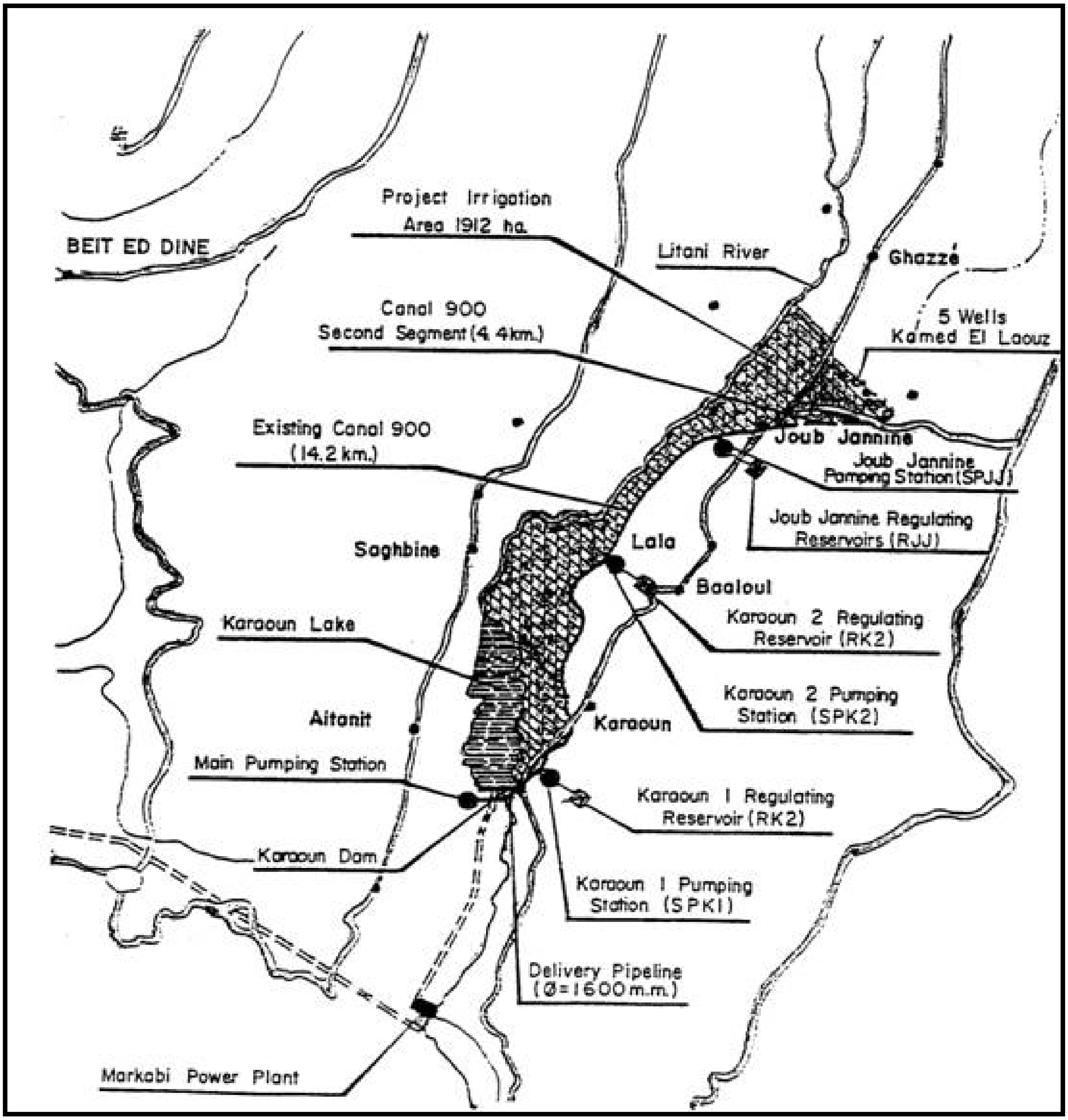


Figure 3. Canal 900 Detail Map

Source: Litani River Authority, General Studies Department, South Bekaa Irrigation District Canal 900-Phase I (2000 Ha) Hydraulic and Technical Specifications. March 2, 2005

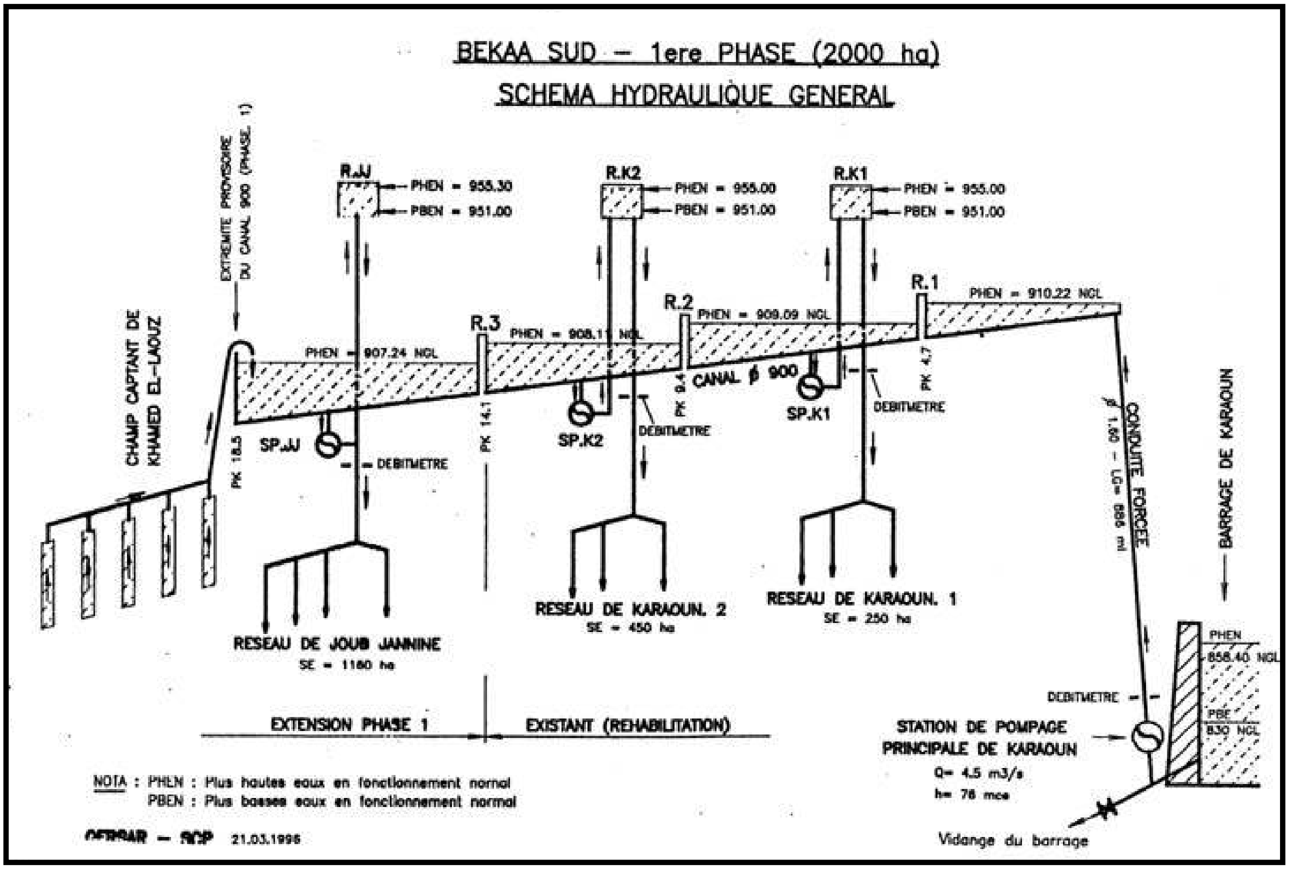


Figure 4. Canal 900 Hydraulic Schematic

Source: Litani River Authority, General Studies Department, South Bekaa Irrigation District Canal 900-Phase I (2000 Ha) Hydraulic and Technical Specifications. March 2, 2005

The canal is designed to deliver 30 million cubic meters per year (m^3/yr). Three pump stations deliver water to regulating reservoirs that subsequently service laterals that irrigate adjacent crop land totaling approximately 2,000 hectares (Ha). Water is delivered from May to September. The canal is dry the remaining 7 months of the year.

The main pump delivering water from Lake Karaoun to the south end of the canal delivers water at an average flow (Q) of 4.5 cubic meters per sec (m^3/s). Although not currently operational, the total delivery capacity of water from the 5 wells at the north end of the canal is 0.275 m^3/s. Water is delivered from regulating reservoirs to laterals at rates ranging from 0.170-0.890 m^3/s. Technical details on capacity and flow are presented in **Appendix A**.

Crops in the Bekaa Valley irrigated by Canal 900 include, in order of predominance: wheat, potatoes, onions, water melons, tomatoes, and apples. Crops such as potatoes are sprinkler irrigated and other vegetables are drip irrigated.

3. Technical Documentation Review

We reviewed the following documents:

1.) Addressing Algae Proliferation in Canal 900 of the Litani River Basin in Lebanon. October 2003. DAI.
2.) Conveyor 800 Mission Report of the Algae Control Specialist. 09-12 February 2004.
3.) Litani River Authority, General Studies Department, South Bekaa Irrigation District Canal 900-Phase I (2000 Ha) Hydraulic and Technical Specifications. March 2, 2005

The following relevant facts are derived from the October 2003 document:

1.) Lake Qaraoun has a mean concentration of phosphorous (P) and nitrogen (N) of 810 mg/L and 5000 mg/L, respectively. These are hypereutrophic conditions highly conducive to the growth of algae. However, the depth of the lake and aeration limit algae growth.
2.) The Canal has a mean concentration of phosphorous and nitrogen of 379 mg/L and 5200 mg/L, respectively. These are also hypereutrophic conditions highly conducive to the growth of algae. Shallow, warm, slow moving water in the canal provide an ideal location for algae growth.
3.) Reduction and/or treatment of Lake Qaraoun water to remove phosphorus (P) and nitrogen (N) is part of the long term program.
4.) The report makes the following recommendations:
    a. Barley straw is the most cost effective and efficacious method of algae control
    b. Resource managers should promote better agricultural practices to limit P and N input to Lake Qaraoun
    c. Canal flow management should be improved to limit stagnation.
5.) Ten (10) locations (C1-C10) were identified in the Canal and sampled. The dates and depths of sample were not reported.
6.) Unabated algae growth in the canal is anticipated to block pumps, sluices, and filters, clog drip emitters, generate foul odors and attract mosquitoes
7.) Undated field observations (presumably from the summer of 2003) indicate that intermittent to moderate algae proliferation is present from stations 1+400 to 4+400 and more prevalent algae is present from stations 4+500 to 17+700. The type(s) of algae present are not presented, but are presumed to be blue-green cyanobacteria typical of climates like that found in the Bekaa Valley.
8.) Algae presence near pumping stations is limited due to high water flows.
9.) LRA uses nets and screens to manually remove algae.

The following relevant facts are derived from the February 2004 document:

1.) Proposed Canal 800 is intended to deliver both irrigation and drinking water thorough a combination of open channels and tunnels from Lake Qaraoun to Chaqra.
2.) Filamentous green algae (*Cladophora* sp.) and sago pond weed (*Potamogeton* cf. pectinatus) were observed at undisclosed downstream locations in Canal 900.
3.) Filamentous green algae (*Sphaeroplea* sp), planktonic blue green algae (*Oscillatoria* cf. agardhii), and green algae (*Scenedesmus* sp) were found in the upper sections of Canal 900.
4.) Methods for aquatic weed control in Canal 800 were suggested. These methods were:
    a. Exclusion of light
    b. Reduction of nutrient supply

    c. Unsuitable substrates for rooting and attachment
    d. Biological control
5.) Chemical herbicides or antifoulings should not be considered for Canal 800 due to the use of the water for food production and domestic consumption.
6.) Like Canal 900, portions of Canal 800 are planned to convey slow moving, high nutrient content water that will be exposed to sunlight and hence prone to algae growth and proliferation. Accordingly, drip irrigation facilities on Canal 800 are expected to be impacted by the anticipated algae growth, but can be removed mechanically (filters, sieves, separators, etc).
7.) Suggestions for control of algae were:
    a. Light reduction using a canal cover or trees.
    b. Reduction of phosphorous loading through construction of wastewater treatment plants,
    c. Modification of agricultural practices,
    d. Modifications to the structure or management of and biomanipulation of the water in Lake Qaraoun, and
    e. Preparation of an extensive survey of the Lake's nutrient dynamics, phytoplankton, zooplankton, and fish,
8.) Canal 800 will have a "upstand" of the canal wall to prevent the introduction of soil into the canal
9.) A filtering facility at the end of the Qelia canal was recommended
10.) Biomass reduction in open sections of the canal should be accomplished using shade from trees and structures and plant-feeding fish (carp).

4. Similarities to California Agriculture

The climate, topography and growing season of Lebanon's Bekaa Valley is similar to that of the central Valley of California. California has around sixty years of experience in algae control in irrigation canals. For example, California's Central Valley Project (CVP) treats algae in nine major concrete-lined canals totaling over 800 km with an agricultural delivery capacity of approximately five billion cubic meters (BCM) for over one million hectares. Because of the likeness of Lebanon's Bekaa Valley to California's Central Valley, successful aquatic weed control strategies employed in California are expected to be similarly successful in Lebanon.

5. Canal 900 Reconnaissance Findings

Site reconnaissance during both the May and August site visits revealed that the following aquatic weeds were present in the canal:

1. Filamentous green algae (*Cladophora* sp.) at all locations; most prevalent at and downstream of K1 pump station. Refer to **Figure 5**.

Figure 5. Filamentous Green Algae

2. Sago pond weed (*Stuckenia pectinatus*) and curly leaf pond weed (*Potamogeton crispus*) at and downstream of the K2 pump station. Refer to **Figures 6 and 7**.

Figure 6. Sago Pond Weed

Figure 7. Curly Leaf Pond Weed

The primary purpose of algae removal is to keep pump screens clean. Screens are located at each of the three pump stations and screen water prior to it being pumped to one of the three storage reservoirs. Refer to **Figure 8**.


Figure 8. Clean Pump Screen at K1

Prior to reaching the screens, algae is currently removed from the canal by hand using rakes and boards placed across the canal. Refer to **Figure 9**. This technique is labor-intensive and must be repeated regularly.


Figure 9. Algae Removal by Hand Upstream of K2

Water conveyed in the canal is pumped to one of three reservoirs where it is stored prior to delivery to farmers. Refer to **Figure 10**.


Figure 10. K1 Reservoir

Water stored in the reservoirs is then gravity flowed to farmers. Depending on the crops grown and the method of irrigation water delivery, irrigation water may be filtered by farmers to remove particulate and undissolved solids, including algae. For example, sand filters are used by farmers to remove solids prior to drip irrigation. Refer to **Figure 11**.

Figure 11. Sand filter (shown on right) and fertilizer injector (shown on left)

Once filtered, irrigation water is used with drip (**Figure 12**) and sprinkler irrigation (**Figure 13**).

Figure 12. Drip Irrigation

Figure 13. Sprinkler Irrigation

Interviews with LRA staff resulted in determining details of canal hydraulic operation, including flow, reservoir use, and water distribution to farmers. A summary of flow characteristics is presented in **Appendix A**.

6. Analysis of Suggested Control Options

Observations made during the site reconnaissance and data provided in the technical documentation reviewed suggest that a variety of aquatic weed control techniques may be considered. Each of these techniques is briefly discussed and evaluated below. Evaluation is based on past experience with these techniques in similar canal environments in California.

Barley straw. A lack of legitimate scientific research exists on the use of barley straw to control algae. Control is presumed to be related to the production of hydrogen peroxide from decomposing barley. Straw bales must be broken apart and allowed to float in the water to

maximize contact time and contact area. Work done to date with barley straw is limited to use in ponds.
Conclusion: This is not a recommended control option. Due to the lack of valid efficacy data and no data on performance in moving water, the use of barley straw is not recommended. Further, the presence of whole and decomposing straw fragments in canal water would likely clog pump intakes and flow regulating structure screens in a manner similar to or worse than the algae that requires control.

Agricultural practices to limit P and N. This is a legitimate suggestion.
Conclusion: The extent to which P and N concentrations in Lake Qaraoun are due to agricultural inputs are not known. However, survey results ("Water Quality Assessment of the Upper Litani River Basin and Lake Qaraoun Lebanon" DAI, October 2003) indicate that domestic wastewater discharge and agrochemical use are major sources of N and P. Assuming that agricultural inputs of N and P to Lake Qaraoun water do in fact occur, reduction of these inputs is important. Methods of control include implementation of Best Management Practices (BMPs) including, but not limited to: erosion control, plant nutrient requirement analysis and nutrient management planning, and grower education. Further analysis and discussion of these BMPs is outside the scope of this work, but would be appropriate for inclusion in a grower education, extension, and outreach program.

Improved canal flow management. This is a legitimate suggestion. According to the Canal 900Hydraulic and Technical Specifications and the February 2004 document referenced previously, the slope of the canal (0.2%) is less than suggested values required to maintain sufficient water velocity to prevent algae proliferation.
Conclusion: The current canal slope is fixed and cannot be changed. Current operation of the canal is demand-based, meaning that the flow in the canal is directly related to the water delivery requirements downstream. Water is only delivered based upon demand, and the rate of delivery is based on the rate of downstream consumption. Hence, canal flow must be matched to water use and canal flow can not be increased without an increase in downstream use. Summer 2005 downstream water use and corresponding flow is approximately 20 % of design capacity and is not anticipated to increase significantly in the near future; therefore canal flow will not be able to be increased.

However, it should be pointed out that canal water is first conveyed to three downstream reservoirs where water is stored and then delivered to farmers. Water stored in these reservoirs is largely replenished during evening hours to limit evaporation losses incurred during the day and to meet demand that is typically higher in the evening. Because water conveyance during the day is limited, flow in the canal during the day is slow and results in higher water temperatures and less shear stress which is optimal for algae establishment and proliferation. Therefore, consideration should be given to decreasing flow during evening hours and increasing flow during daylight hours to decrease daytime water temperatures and increase shear stress on algae adhered to the canal banks. The combination of decreased water temperature and increased shear stress may limit algae establishment and proliferation. Advantages gained with this suggested change in canal flow regime must be weighed against potential costs related to evaporative losses, actual down-stream water demand, and storage capacity at the three reservoirs.

Finally, effective management of aquatic weeds in the canal will result in the ability of the canal to convey water at design flows. Further, improvements in water quality (i.e., less algae present to clog farmer's drip emitters and filters) are anticipated to increase the demand for water delivery. An increase in demand will require an increase in flow. An increase in flow may result in less algae establishment and proliferation as discussed above.

Exclusion of light. The exclusion of light from the canal will limit the amount of algae growth. However, methods of light exclusion suggested in the reviewed documents are infeasible. Conclusion. This is not a recommended control option. Specifically, depending the type of cover selected, exclusion of light may not be sufficient to prevent or significantly limit algae growth. Placement of a cover over the canal would impede canal monitoring maintenance activities. The use of canal covers in California is non-existent. Although some shade would be provided by the planting of trees adjacent to the canal, a high density and close spacing of trees along the canal would be required to provide adequate shade to disrupt light penetration and algae growth. It would take several years to develop mature enough trees to result in sufficient density to provide the needed shade. Further, placement of trees close to the canal impedes canal inspection and maintenance and tree root damage to the canal may occur.

Remove canal debris. This is a legitimate suggestion. Numerous locations, particularly near bridge abutments, along the canal exist were soil enters the canal. This soil subsequently provides nutrients and/or rooting media for either sago and/or curly leaf pond weed to establish and proliferate in the canal.
Conclusion. This is a recommended procedure and should be part of regular canal maintenance conducted during the winter when the canal is not in use. Recommended steps include:

1. To the extent practicable, the canal bottom should be thoroughly cleaned of all soil and debris. Weed seed may be present in canal cracks and joints and should be removed using pressure washing equipment or other suitable device
2. Retaining walls should be constructed at bridge abutments to prevent soil from entering the canal.
3. Ground on the side of the canal should be graded away from the canal so that during rain events no soil is washed into the canal.
4. Residents adjacent to the canal should be instructed on how to prevent soil from entering the canal from their property. Further, they should not be allowed to house animals close to the canal to prevent nutrients and bacteria in animal waste from entering the canal.

Biological control. Fish (carp or tilapia) are capable of eating aquatic weeds and/or algae. The use of these fish will disrupt the existing biodiversity of the region, is limited by their uncertain availability, high cost, and need for annual replacement. Further, due to the close proximity of numerous homes to the canal, these fish may regularly be removed and eaten by local residents. Last, uncontrolled introduction and release of non-native species to the Litani River basin may disrupt the existing biodiversity of the region.
Conclusion. This is not a recommended control strategy.

Use of Chemical herbicides. The February 2004 document indicated that herbicides should not be considered due to the use of the water for food production and domestic consumption. No analysis of risk, exposure, or toxicity was presented as rationale for this recommendation. Conclusion: The recommendation that herbicides should not be used lacks sufficient analysis and rationale. The use of several herbicides, including copper-containing compounds, have historically been recognized as components of an Integrated Pest Management (IPM) approach for algae control in California. Combined with data gathered from regular site reconnaissance and establishment of acceptable weed thresholds, IPM uses a combination of chemical, mechanical, biological and operational techniques to control weeds.

The use of herbicides is an integral part of IPM. The selection of an appropriate herbicide takes into account numerous factors including efficacy, toxicity to non-target organisms, and risks to applicators and residents near the application area. Without first analyzing these selection factors, the use of herbicides as part of an IPM approach for control of aquatic weeds in Canal 900 should not be dismissed.

A summary of the algae control options discussed above are presented in **Table 1**.

TABLE 1. Summary of Control Options

Method	Positives	Negatives	Conclusion
Chemical			
Copper Sulfate	Inexpensive, easy, effective, safe	Leaves copper, kills fish	Implement
Chelated Copper	Effective	Expensive, leaves copper, kills fish	Do Not Implement
Acrolein	No Residue, highly effective	Highly toxic, requires special training	Do Not Implement
Hydrogen Peroxide	No Residue	Unproven in canals	Do Not Implement
Mechanical			
Manual Removal	Available labor, past	Limited effectiveness,	Implement
Remove Canal Debris	Removes dirt, improves flow, prevents weeds next year	Must be repeated every year	Implement
Bank Grading	Prevents Soil in Canal	None	Implement
Biological			
Apply Barley Straw	May slow algae production	Not proven; may clog pump screens	Do Not Implement
Use of Fish (Carp or Tilapia)	May eat algae and weeds	Must be repeated every year; may be removed by residents	Do Not Implement
Exclusion of Light (Trees)	May prevent algae from growing	Takes time to grow, only partial shade	Do Not Implement
Operational			
Agricultural Practices to Limit N & P	May prevent algae from growing	Control of the source of N & P can be difficult	Implement if Possible; Provide education, extension and outreach
Exclusion of Light (Shade Structure)	May prevent algae from growing	Expensive, hinders canal maintenance	Do Not Implement
Improved Canal Flow Management	May prevent algae from growing	Current insufficient water demand to justify sustained high volume flow	Implement if Possible

7. Recommended Algae Control Solutions

Based upon the analysis of control options presented above, an IPM approach to the control of aquatic weeds in Canal 900 is recommended. Components of the recommended IPM approach include:

Biological Control:
None recommended at this time.

Mechanical Control:

1. The canal bottom should be thoroughly cleaned of all soil and debris. Weed seed may be present in canal cracks and joints and should be removed using pressure washing

equipment or other suitable device
2. Retaining walls should be constructed at bridge abutments to prevent soil from entering the canal.
3. Ground on the side of the canal should be graded away from the canal so that during rain events no soil is washed into the canal.
4. Residents adjacent to the canal should be instructed on how to prevent soil from entering the canal from their property. Further, they should not be allowed to house animals close to the canal to prevent nutrients and bacteria in animal waste from entering the canal.
5. Algae should continue to be removed by hand from the canal and pump intake structures

Operational Control:
1. Consider decreasing flow during evening hours and increasing flow during daylight hours to decrease daytime water temperatures and increase shear stress on algae adhered to the canal banks.

Chemical Control:
1. Screen and select appropriate herbicide(s) based upon factors including ease of use, efficacy, toxicity to non-target organisms, and risks to applicators and residents near the application area.

8. Analysis of Herbicide Control Options

As previously discussed, the climate, topography and growing season of Lebanon's Bekaa Valley is similar to that of the central Valley of California. Management of aquatic weeds in irrigation canals in California have historically relied on an IPM approach that includes the use of herbicides. Several herbicides have proven effectiveness and based on the screening and selection factors mentioned above, are evaluated and summarized in the **Table 2** below.

TABLE 2. Summary of Herbicide Control Options

Herbicide	Ease of Use	Efficacy on Algae	Toxicity to Non-Target Organisms	Risk to Applicators	Risk to Residents
Copper Sulfate	Easy	Good	None	Low	Low
Chelated Copper	Moderate	Good to Very Good	Low	Low	Low
Acrolein	Difficult	Excellent	High	High	High
Hydrogen Peroxide	Difficult	Good	High	Moderate	Low

At this time, copper sulfate is readily available to the LRA, has proven efficacy on the algae species present in the canal, and when used according to label directions will not likely cause adverse impact to aquatic environments in which it is used. It is a dry solid that is easy to handle and does not possess acute or chronic human health risks. Further, when copper-treated water is used for crop irrigation, it is not known to be phytotoxic to the crops currently grown in the area.

In addition, the target concentration of copper in the canal will not exceed the US Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for drinking water of 1.3 mg/L.

Last, the anticipated amount of copper delivered annually per irrigated hectare of land per irrigation year is less than the maximum amount suggested by the European Union (EU) that can be added to soil annually for organic food production.

9. Algae Control Testing and Validation

Small scale testing and validation of algae control using herbicides was accomplished from 16-26 May 2005. Testing took place at three locations in the canal. Refer to **Figure 14**. Copper sulfate was introduced into the canal using the dosing schedule shown in **Table 3**. A concentration of between 0.5 and 1 milligram per Liter (mg/L or parts per million [ppm]) was initially targeted to evaluate the degree of algae control. Good to very good control of algae was noted in 3 days. Refer to **Figures 15 and 16**.

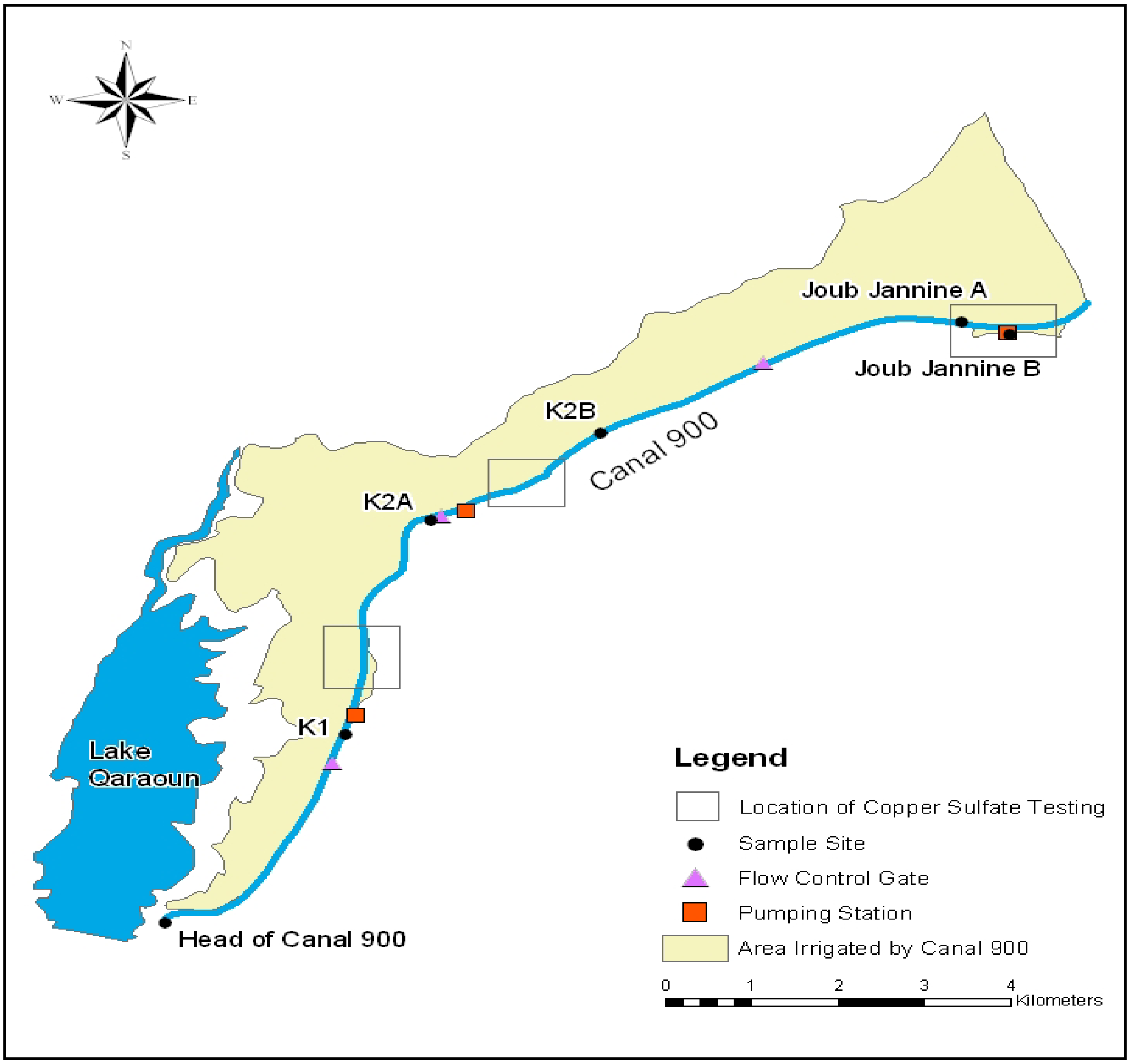


Figure 14. Locations for copper sulfate testing. 20-23 May, 2005.

Figure 15. 20 May 2005

Figure 16. 23 May 2005

The amount of copper sulfate added to the canal in June and July was tapered to a dose of 0.1mg/L and exhibited acceptable control until middle July. Increased algae presence was noted by LRA staff in late July. During the site reconnaissance done from 1-5 August, 2005, significant amounts of algae were noted, particularly from at and downstream of the K2 regulating reservoir. As a result, the dosing target was increased to 1 mg/L for the month of August.

Application of copper sulfate was made according the scope of work (SOW) contained in **Appendix B**.

On both the May and August field reconnaissance visits, LRA staff were trained in using **Table 3** to estimate the amount of copper sulfate required per location and date in order to achieve target copper concentrations. In addition, LRA staff were trained in appropriate techniques for safely and effectively measuring and applying copper sulfate to the canal. Refer to **Appendix B**.

Evaluation and testing of mechanical control of algae is recommended for implementation during the fall 2005 and winter 2006. Evaluation and testing of operational control is recommended for implementation in the summer 2006.

10. Water Quality Monitoring

DAI and LRA staff completed water sampling and testing as indicated in **Table 3**. Concentrations from the sampling event of 10 June 2005 are shown spatially in **Figures 17-19**.

Table 3. Canal 900 Dosing Targets and Schedule

			ACTION				
Date (1)	Location (2,3)	Target CuSO4 Water Concentration (mg/L)	Amt (Kg) CuSO4 Added to **Each** Location (4)	Measure Water Quality (5,6)	Weekly Canal Total (Kg)	Monthly Total (Kg)	Seaso Runnin Total (K
3-Jun	H, K1, K2, JJ	0.5	28.0	Y	112		
7-Jun				Y			
10-Jun	H, K1, K2, JJ	0.5	28.0	Y	112		
14-Jun				Y			
17-Jun	H, K1, K2, JJ	0.2	11.3	Y	45		
21-Jun							
24-Jun	H, K1, K2, JJ	0.2	11.3	Y	45		
28-Jun						314	314
1-Jul	H, JJ	0.1	11.3	Y	22.5		
5-Jul							
8-Jul	H, JJ	0.1	11.3	Y	22.5		
12-Jul							
18-Jul	H, JJ	0.1	11.3	Y	22.5		
22-Jul							
28-Jul	H, JJ	0.1	11.3	Y	22.5	90	404
1-Aug							
8-Aug	H, K1, K2, JJ	1	26.3	Y			
12-Aug	H, K1, K2, JJ	1	26.3		210		
15-Aug	H, K1, K2, JJ	1	26.3	Y			
19-Aug	H, K1, K2, JJ	1	26.3		210		
22-Aug	H, K1, K2, JJ	1	26.3	Y			
26-Aug	H, K1, K2, JJ	1	26.3		210		
29-Aug	H, K1, K2, JJ	0.5	13.1	Y		630	1034
2-Sep	H, K1, K2, JJ	0.5	13.1		105		
5-Sep	H, K1, K2, JJ	0.5	13.1	Y			
9-Sep	H, K1, K2, JJ	0.5	13.1		105		
12-Sep	H, K1, K2, JJ	0.2	5.3	Y			
16-Sep	H, K1, K2, JJ	0.2	5.3		42.0		
19-Sep				Y			
23-Sep							
26-Sep				Y	0		
29-Sep				Y		252	**1286**

Notes:

(1):Make all applications as **EARLY IN THE MORNING** as possible when flow is slowest. Assume flow = 30,000 m3/day

(2):H=Head of canal; K1 = Karaoun 1 Pump Station; K2 = Karaoun 2 Pump Station; JJ = Joub Jannine Flow Regulator

(3):Make All applications **DOWNSTREAM** of the pump intake

(4):Apply copper sulfate to water slowly and evenly to maximize distribution in the canal and minimize settling to canal bottom. If algae presence is below tolerable levels, switch application frequency from once/7 days to once/14 days. Conversely, if algae presence exceeds tolerable levels, change frequency back to once/7 days or to once/3 days until algae is below tolerable levels.

(5) Measurements with the Hydrolabs Sonde: Temperature, Specific Conductivity, Dissolved Oxygen, Salinity, Total Dissolved Solic pH, and nitrate.

(6) Measurements with Hach test strips: pH, copper, phosphate, nitrate, ammonia, and hardness.

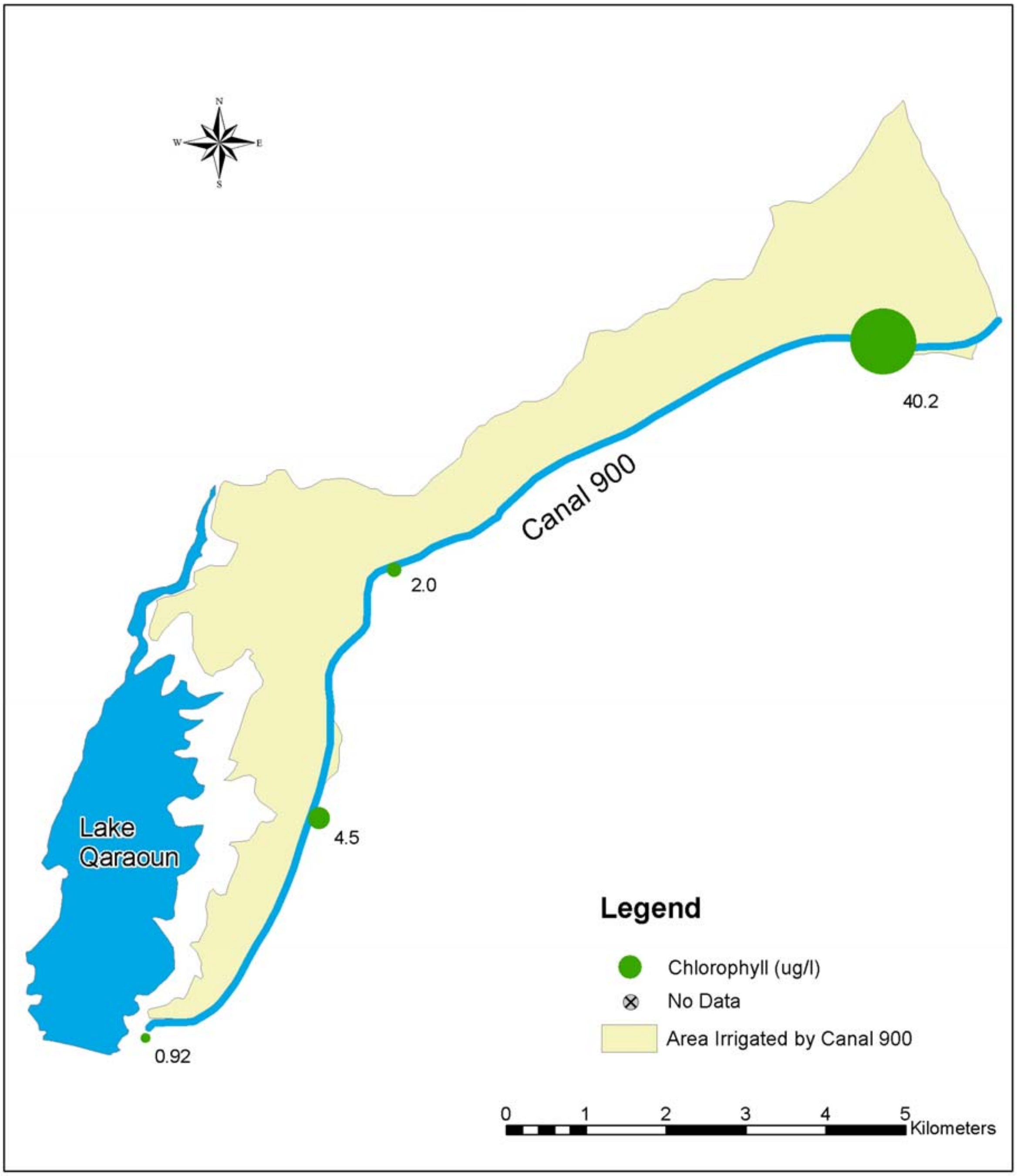


Figure 17. Chlorophyll Concentrations on 10 June 2005. Note that values are micrograms per Liter (ug/l).

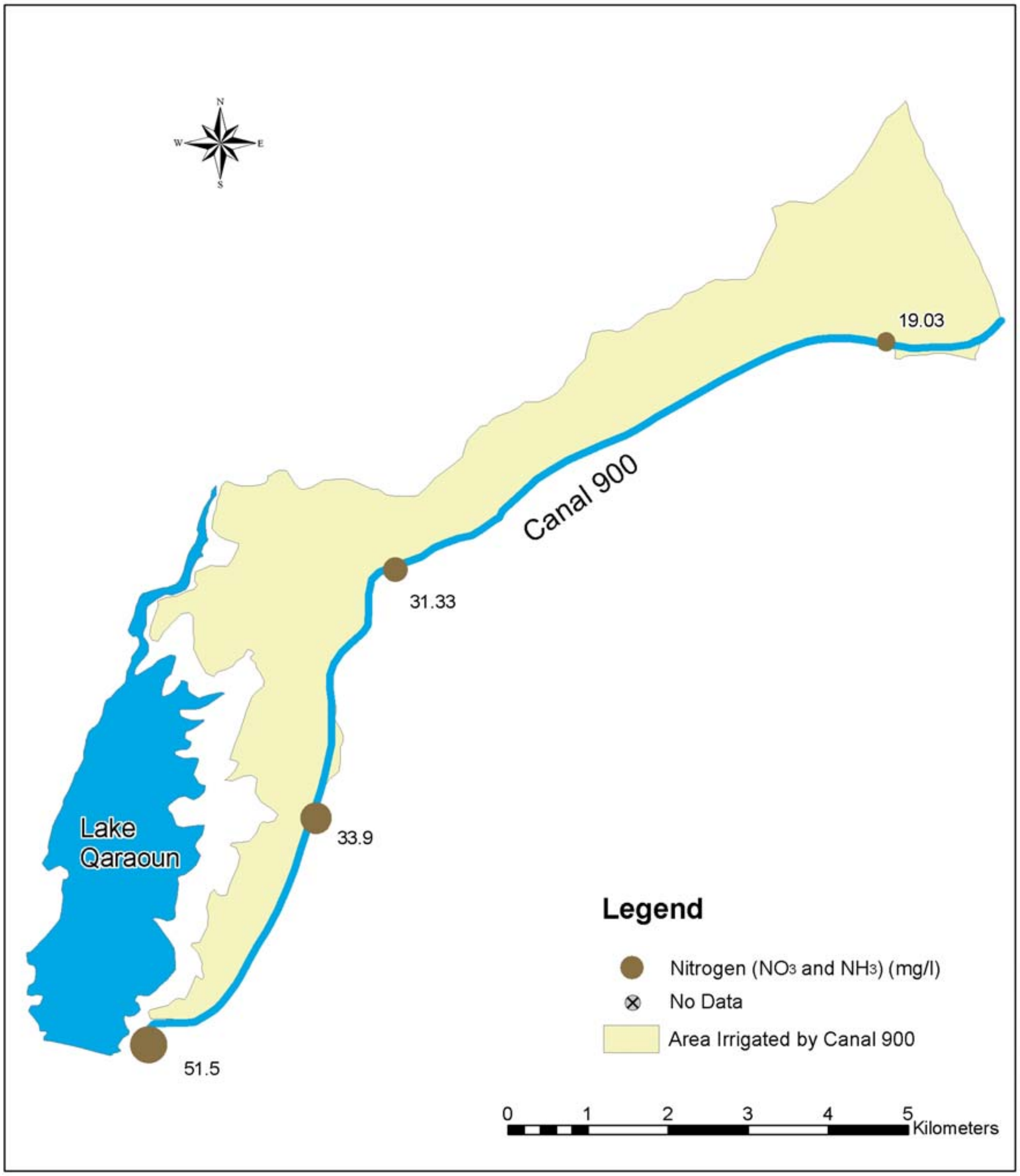


Figure 18. Nitrogen (nitrate and ammonia) concentrations on 10 June 2005

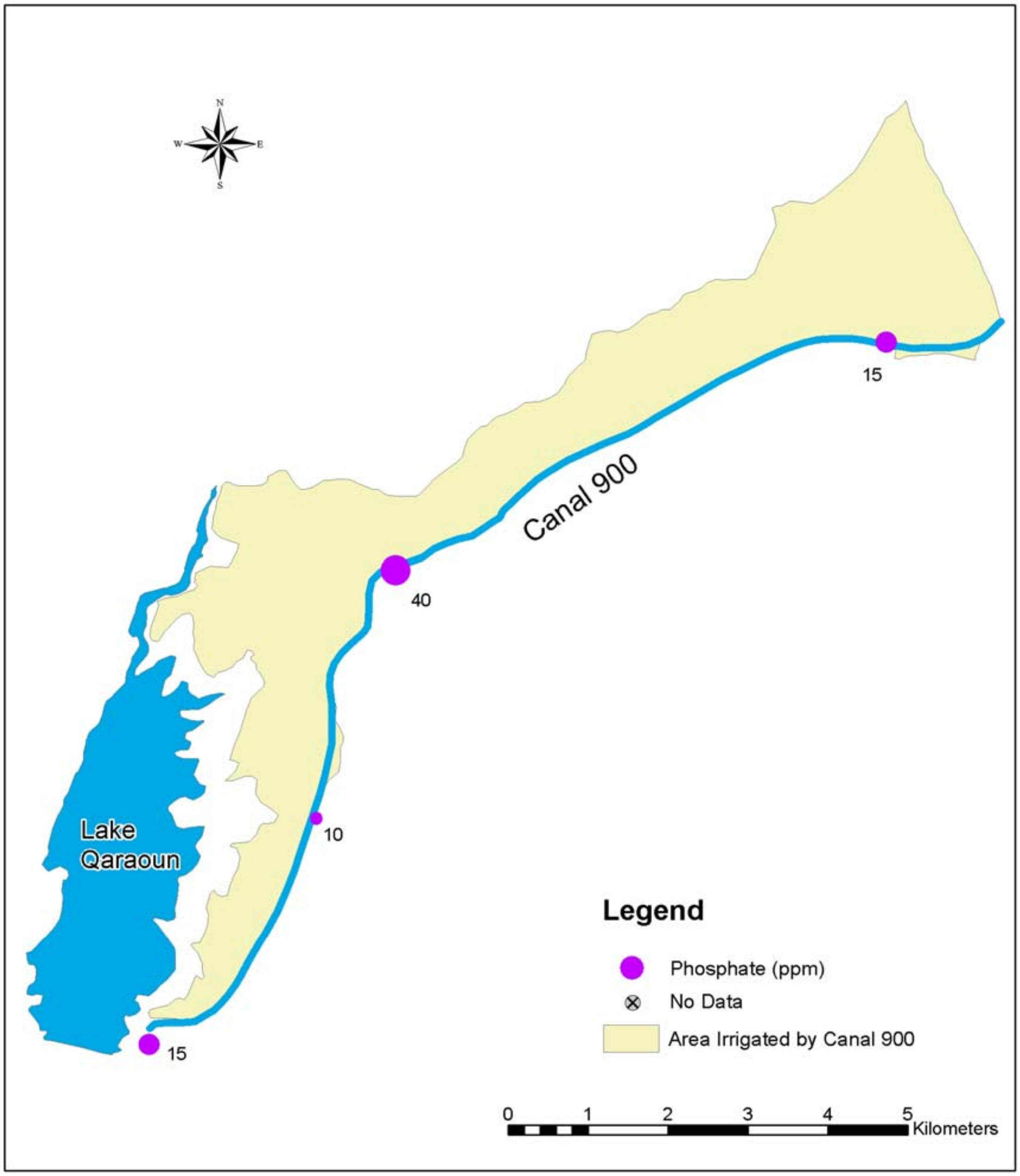


Figure 19. Phosphate concentrations on 10 June 2005

Analyte concentrations for sampling events in the canal between 26 May and 14 June 2005 are shown in **Figures 20- 24**.

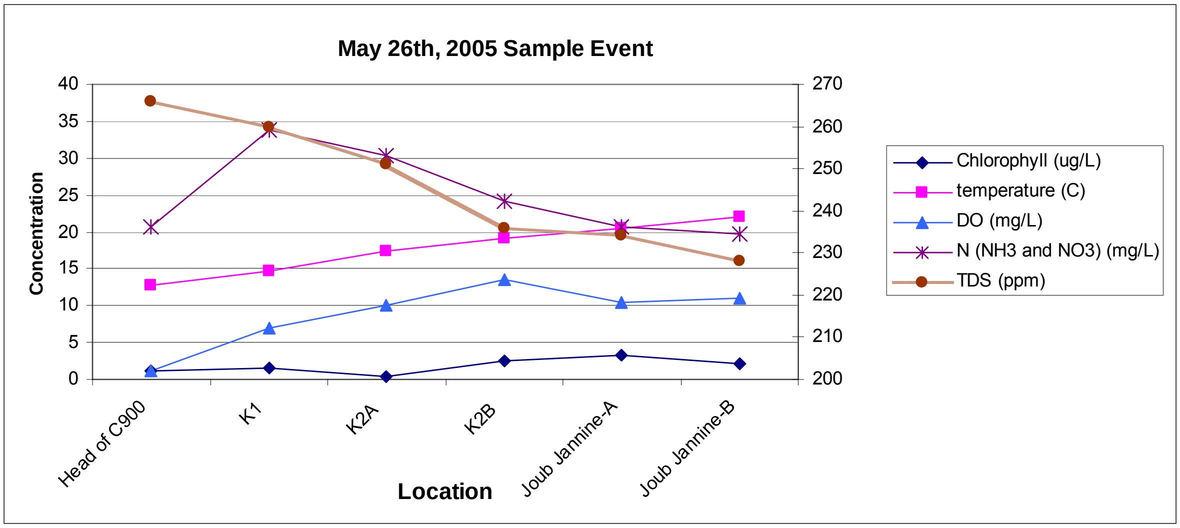


Figure 20. 26 May 2005 data. Values for Total Dissolved Solids (TDS) are shown on the right axis.

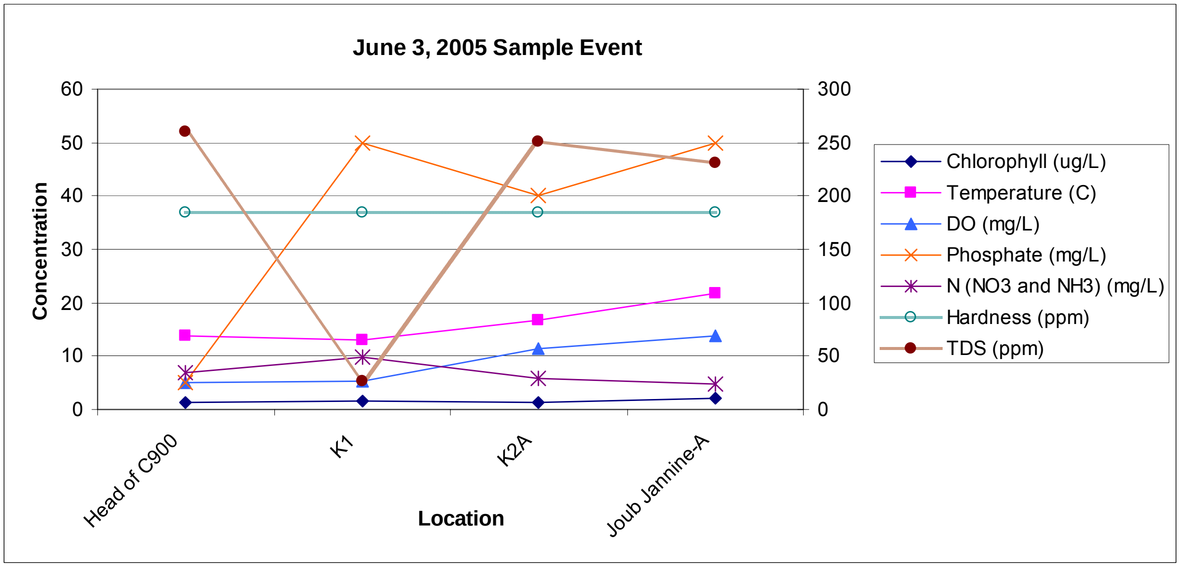


Figure 21. 3 June 2005 data. Values for Total Dissolved Solids (TDS), Hardness, and Nitrogen (N) as NH_3 and NO_3 are shown on the right axis.

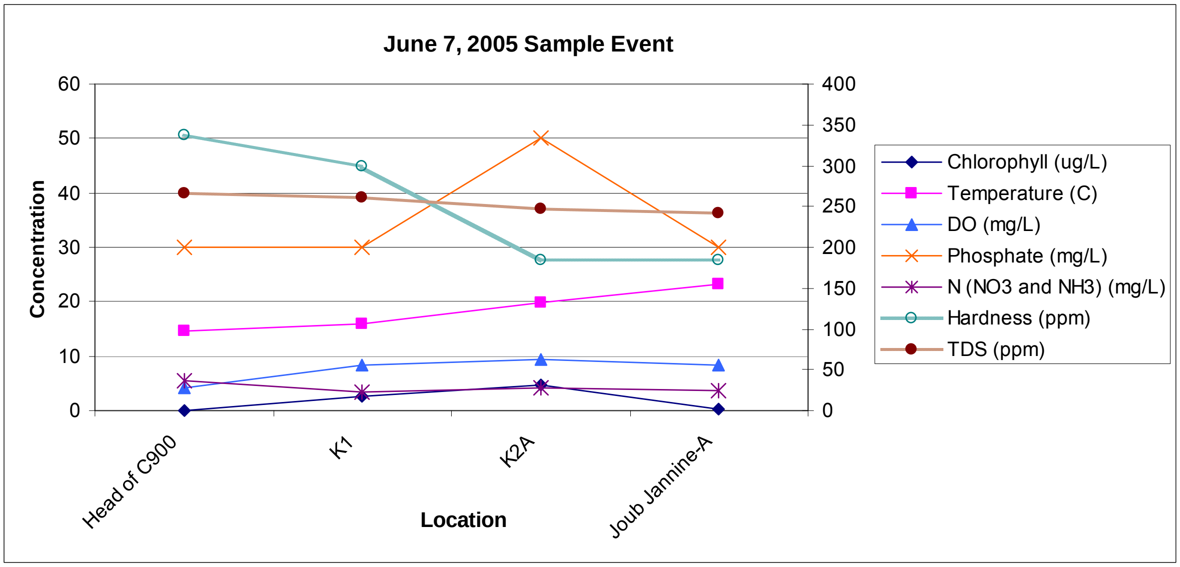


Figure 22. 7 June 2005 data. Values for Total Dissolved Solids (TDS), Hardness, and Nitrogen (N) as NH_3 and NO_3 are shown on the right axis.

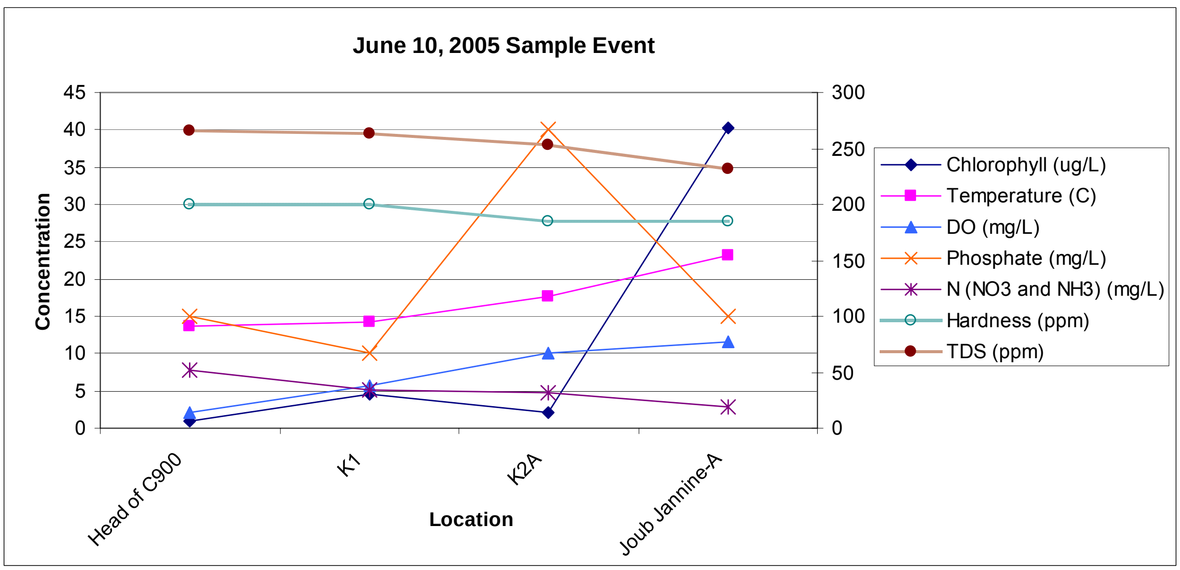


Figure 23. 10 June 2005 data. Values for Total Dissolved Solids (TDS), Hardness, and Nitrogen (N) as NH_3 and NO_3 are shown on the right axis.

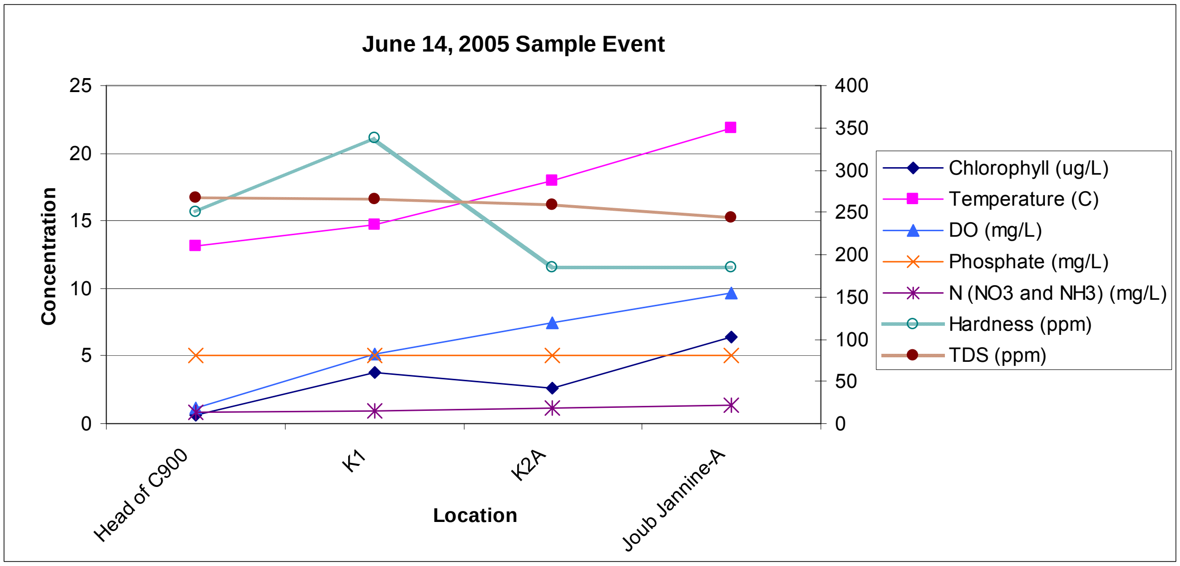


Figure 24. 14 June 2005. Values for Total Dissolved Solids (TDS), Hardness, and Nitrogen (N) as NH_3 and NO_3 are shown on the right axis.

The 10 June 2005 sampling event showed chlorophyll being highest at the Joub Janine-A site, with much lower concentrations upstream (**Figure 17**). The value of 40.2 ug/L at this site was the highest measured at any station within the sample timeframe (between 26 May and 14 June 2005), and is within the range indicating eutrophication as indicated by biomass production (FORWARD Program, 2003). The finding of high chlorophyll values at Joub Jannine is consistent with high concentrations of algae at this location.

A concentration gradient was observed for nitrogen (nitrate [NO_3^-] and ammonia [NH_4^+]), with the highest level at the Head of Canal sampling site and decreasing downstream (**Figure 18**). All nitrogen measurements in the sample timeframe were above 5 mg/L, which is considered hypereutrophic (FORWARD Program, 2003).

Phosphate was highest during the June 10, 2005 sampling event at the K2A site, with equal concentrations at the Head of Canal and Joub Janine-A sites (**Figure 19**). All phosphate measurements were in the hypereutrophic range. The high concentration of phosphorous at the K2A site may be a result

The N:P ratio of all stations within the sample timeframe (except the May 26, 2005 sample event when P was not measured) was below 10, indicating that phytoplankton growth is nitrogen limited. In general, an N:P ratio below 10 indicates nitrogen limits growth, while growth is phosphorus limited at values above 10 (Horne and Goldman, 1994).

As expected, canal water temperature increases with time. Refer to **Figure 25**. Based on water quality data gathered by DAI and LRA personnel, increases in chlorophyll concentration appears to precede observed algae counts. Refer to **Figures 26-27**. In addition, relative to other locations in the canal, high algae densities and chlorophyll concentrations were observed at the end of the canal at Joub Jannine and K2. This finding is consistent with the high water temperature and slow or non-existent flow that is present in these locations.

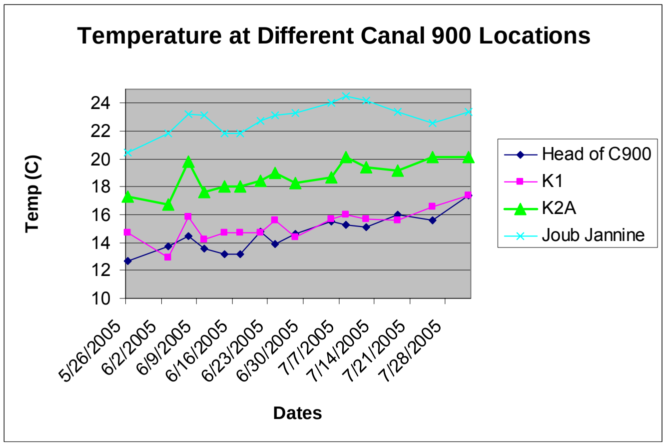


Figure 25. Temperature v Time at Different Locations

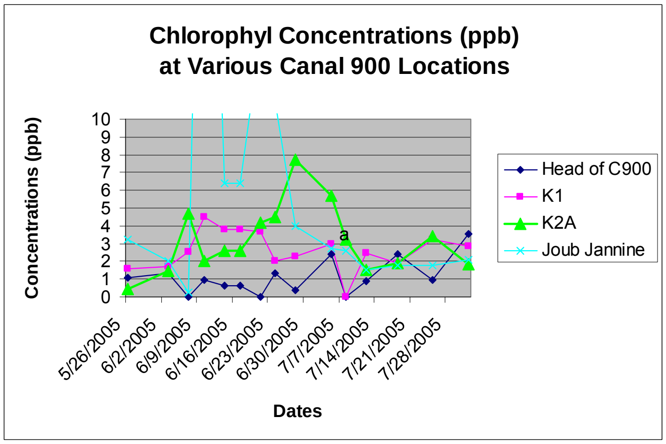


Figure 26. Chlorophyll v Time at Different Locations

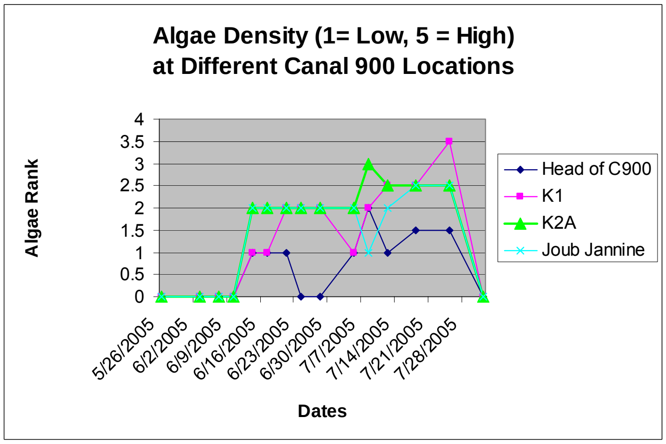


Figure 27. Algae Density v Time at Different Locations

Figure 28 indicates that phosphorous concentrations spiked several times at the head of the canal. Downstream locations did not show similar dramatic phosphorous increases, but maintained a relatively constant concentration throughout the period of sampling. The impact that these phosphorous spikes at the head of the canal have on algae growth is not clear. However, regardless of the sporadic increases in phosphorous at the head of the canal, the overall baseline abundance of phosphorous in the canal in combination with a high baseline nitrate nitrogen concentration (**Figure 29**) clearly supports and enhances algae growth.

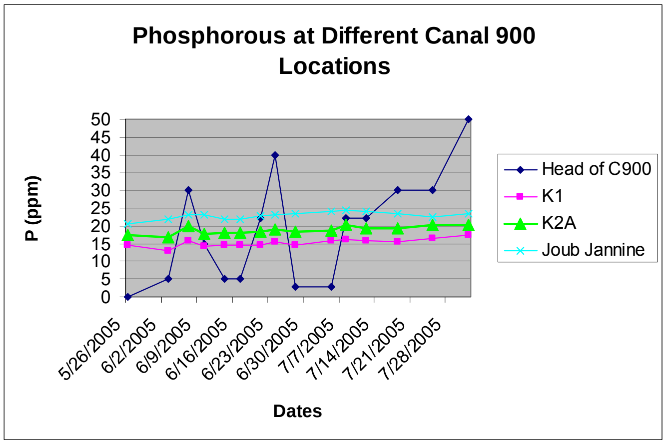


Figure 28. Phosphorous v Time at Different Locations

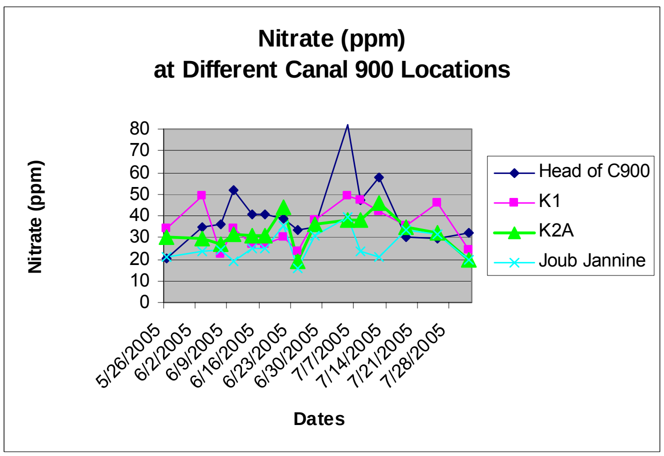


Figure 29. Nitrate v Time at Different Locations

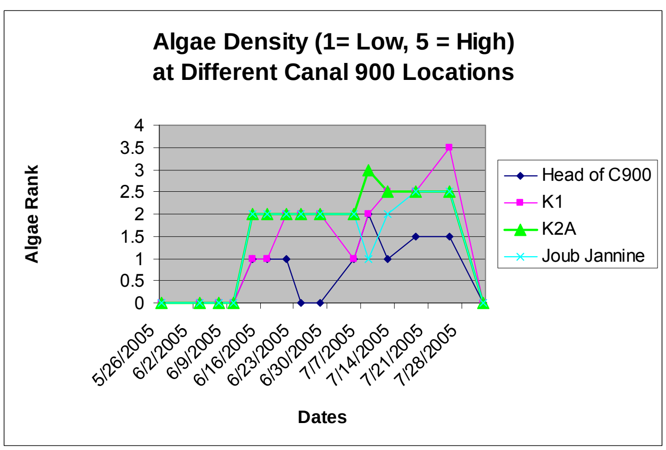


Figure 27. (repeated for convenience). Algae Density v Time at Different Locations

11. Soil and Crop Sampling and Analysis

DAI staff collected numerous background soil, soil samples collected in the area irrigated by Canal 900, and crop samples and submitted those samples for analysis of copper, chromium, and cadmium. Refer to **Figure 30** for locations of samples.

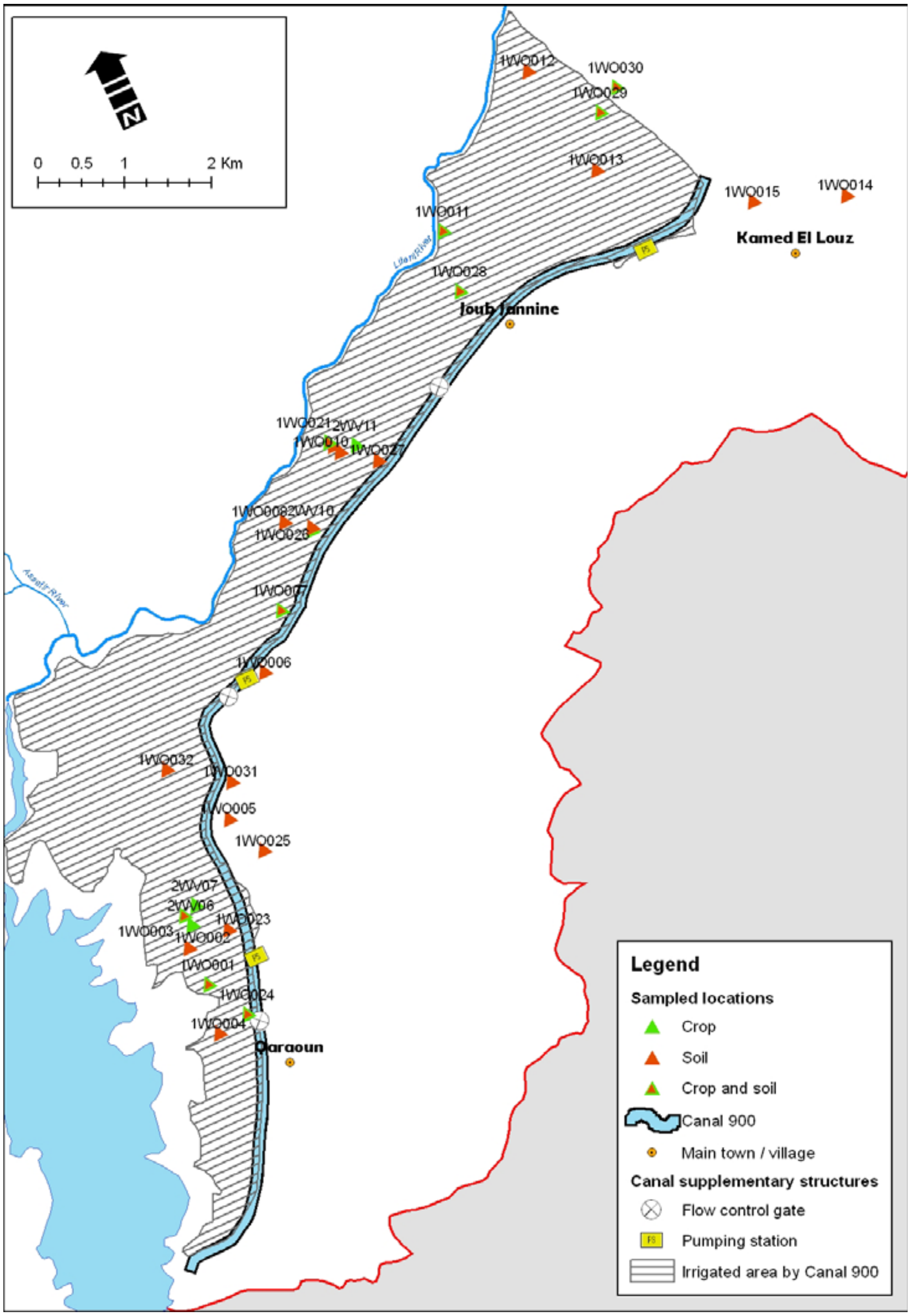


Figure 30. Crop and Soil Sample Location Map

A summary and statistical analysis of this data is presented below:

Location	# Samples	Ave	Max	Min	Std Deviation	Range (1)
Canal 900 Irrigated Soil	23	36.5	88.0	3.0	22.27	36-81
Background Soil	4	24.3	28.6	4.0	5.88	24-36
Crops	15	1.0	2.7	0.4	0.67	1-2.4

Notes:
All values in mg/Kg Copper
(1) Range is 95% confidence interval (average $\pm$ 2 standard deviations)

As the data suggest, the soil in the area irrigated by Canal 900 has copper at a concentration that appears to be statistically significantly higher than the soil in background areas not irrigated by Canal 900. The reason for this is not known. This data does, however, provide background information for LRA staff so that the impact to area soils as a result of using copper in Canal 900 irrigation water can measured.

The location of crop samples is also shown on **Figure 30.** Like with the soil data discussed above, the concentration of copper in the crops sampled provides useful background data to track the impact, if any, that the presence of copper in irrigation water has on crops.

12. References

Conveyor 800 Mission Report of the Algae Control Specialist, 2004, Hydro-agricultural Development of South Lebanon, Irrigation and Water Supply Scheme-Conveyor 800, LITANI River Authority, February 2004

FORWARD, 2003b, Addressing algae proliferation in canal 900 of the Litani River Basin in Lebanon, DAI & WESS, United States Agency for International Development, Beirut, Lebanon, October 2003

Litani River Authority, 2005, General Studies Department, South Bekaa Irrigation District Canal 900-Phase I (2000 Ha), Hydraulic and Technical Specifications, March 2005

Horne, A.J., and C.R. Goldman,1994. Limnology. Second Edition, McGraw Hill

CANAL DIMENSIONS

Reach	Start (Km from Head)	End (Km from Head)	Dist (m)	Width (m)	Water Depth (m)	Approximate Area (m2)	Capacity (m3)
1	0	4.7	4700	4	1.5	6	28200
2	4.7	9.4	4700	4	1.5	6	28200
3	9.4	14.1	4700	4	1.5	6	28200
4	14.1	18.5	4400	4	1.5	6	26400
							111000

CANAL PUMPING RATES

MAXIMUM

Pump	Reservoir Capacity (m3)	Q (m3/s)	Q (m3/min)	Q MAX (m3/hr) (1)	Q MAX (m3/day)
K1	1200	0.07	4.2	252	6048
K2	1700	0.145	8.7	522	12528
JJ	5000	0.56	33.6	2016	48384
				2790	66960

NIGHT

Pump	Reservoir Capacity (m3)	Q (m3/s)	Q (m3/min)	Q NIGHT (m3/hr) (1)	Q NIGHT (m3/day)
K1	1200	0.06	3.6	216	5184
K2	1700	0.12	7.2	432	10368
JJ	5000	0.4	24	1440	34560
				2088	50112

DAY

Pump	Reservoir Capacity (m3)	Q (m3/s)	Q (m3/min)	Q DAY(m3/hr) (1)	Q DAY(m3/day)
K1	1200	0.01	0.6	36	864
K2	1700	0.05	3	180	4320
JJ	5000	0.1	6	360	8640
				576	13824

TYPICAL DAY CANAL PUMPING RATES (1)

Pump	Q Day (m3/12 hr DAY)	Q Night (m3/12 hr NIGHT)	Q TTL (m3/24 hr "typical" day)	Irrigation Season Length (Day)	Annual Water Delivery (Mm3)
K1	432	2592	3024		
K2	2160	5184	7344		
JJ	4320	17280	21600		
	6912	**25056**	**31968**	180	**5.8**

RESERVOIR DATA

Reservoir	Volume (m3)	Irrigated Area (Ha)	Irrigation Rate (m3/Ha 7 hr Day) (2)	Req'd Delivery Capacity (m3/Day)	Reservoir Cycles
K1	1200	250	16.4	4095	3.4
K2	1700	450	16.4	7371	4.3
JJ	5000	1160	16.4	19001	3.8
				30467	

Notes:

(1) Per Ali, Operations Superintendant, Litani River Authority, May 24, 2005.

(2) Based on 0.65 l/sec per irrigated Ha. Reference: LRA S. Bekaa Irrigation District Canal 900 Phase I Hydraulic & Technical Specifications, 02 Mar 05, page 3.

(3) Intentionally left blank.

Time Required to Empty Canal (Days)	3.5

DOSING REQUIREMENTS

Target CuSO4 Conc (ppm)	CuSO4 Required (Kg) (4)	CuSO4 Required Per Week (Kg) (5)	CuSO4 Required Per Month (Kg)	CuSO4 Required Per 6 Month Irrigation Season (Kg)	Ha (6)	CuSO4 Kg/Ha (7,9)	EU Max (Kg/Ha) (8)
0.2	22.2	45	179	1074	575	***1.9***	6
0.5	55.5	112	448	2685	575	***4.7***	6
1	111.0	224	895	5371	575	9.3	6
1.5	166.5	336	1343	8056	575	14.0	6
2	222.0	448	1790	10741	575	18.7	6

Notes:

(4) Based on total canal volume of approximately 111,000 m^3 as per above Canal Dimension Section above

(5) Based on typical daily flow of 32,000 m^3 and 3.5 days to empty canal.

(6) Based on typical irrigation rate of 10,000 m3/Ha/Irrigation year. Assuming 5.8 Mm3 are used per irrigation year, then:6,000,000/10,000 = 575Ha

(7) ***Italic and Bold*** values below suggested EU value.

(8) European Union (EU) suggested maximum allowable amount of copper added to soil annually for organic food production. See: http://www.ifst.org/hottop24.htm

(9) Target copper concentrations of 1, 1.5, and 2 ppm if sustained over an entire season will exceed the EU suggested maximum allowable amount of copper. The sustained use of these target concentrations is not anticipated. However, temporary increases in target copper concentration may be required to manage significant algae presence and is acceptable ove short periods of time.

Scope of Work (SOW)
for the Control of Algae in Canal 900

Table of Contents

1. The Use of Integrated Pest Management (IPM)

An Integrated Pest Management (IPM) approach to the control of aquatic weeds in Canal 900 will be used. Combined with data gathered from regular site reconnaissance and establishment of acceptable weed thresholds, IPM uses a combination of chemical, mechanical, biological and operational techniques to control weeds.

The use of herbicides is an integral part of IPM. The selection of an appropriate herbicide takes into account numerous factors including efficacy, toxicity to non-target organisms, and risks to applicators and residents near the application area. Consideration of these factors provides a basis for the selection of appropriate herbicide(s) as part of the IPM approach for control of aquatic weeds in Canal 900.

Components of the Canal 900 IPM approach include mechanical, operational and chemical control techniques. Implementation details and timing of these control techniques are presented below. No biological control is recommended at this time.

2. Summer Activities: Chemical Control

Work accomplished in May through and August 2005 identified copper sulfate as an effective chemical control for algae during summer months when water is flowing in the canal. Copper sulfate should be applied according to the application schedule shown in **Table 3**.

It must be pointed out that the schedule shown in **Table 4** is **only an example and actual application rates. Locations, times and amounts of copper sulfate need to be adjusted depending on the severity of algae presence.** Depending on the degree of control achieved, algae should continue to be removed by hand from the canal and pump intake structures as needed.

Table 4. Copper Sulfate Application Schedule

Date (1)	Location (2,3)	Target CuSO4 Water Concentration (mg/L)	ACTION Amt (Kg) CuSO4 Added to **Each** Location (4)	Measure Water Quality (5,6)	Weekly Canal Total (Kg)	Month Total (Kg)	Season Total (Kg)
3-Jun	H, K1, K2, JJ	0.5	28.0	Y	112		
7-Jun				Y			
10-Jun	H, K1, K2, JJ	0.5	28.0	Y	112		
14-Jun				Y			
17-Jun	H, K1, K2, JJ	0.2	11.3	Y	45		
21-Jun							
24-Jun	H, K1, K2, JJ	0.2	11.3	Y	45		
28-Jun						314	314
1-Jul	H, JJ	0.1	11.3	Y	22.5		
5-Jul							
8-Jul	H, JJ	0.1	11.3	Y	22.5		
12-Jul							
18-Jul	H, JJ	0.1	11.3	Y	22.5		
22-Jul							
28-Jul	H, JJ	0.1	11.3	Y	22.5	90	404
1-Aug							
8-Aug	H, K1, K2, JJ	1	26.3	Y			
12-Aug	H, K1, K2, JJ	1	26.3		210		
15-Aug	H, K1, K2, JJ	1	26.3	Y			
19-Aug	H, K1, K2, JJ	1	26.3		210		
22-Aug	H, K1, K2, JJ	1	26.3	Y			
26-Aug	H, K1, K2, JJ	1	26.3		210		
29-Aug	H, K1, K2, JJ	0.5	13.1	Y		630	1034
2-Sep	H, K1, K2, JJ	0.5	13.1		105		
5-Sep	H, K1, K2, JJ	0.5	13.1	Y			
9-Sep	H, K1, K2, JJ	0.5	13.1		105		
12-Sep	H, K1, K2, JJ	0.2	5.3	Y			
16-Sep	H, K1, K2, JJ	0.2	5.3		42.0		
19-Sep				Y			
23-Sep							
26-Sep				Y	0		
29-Sep				Y		252	**1286**

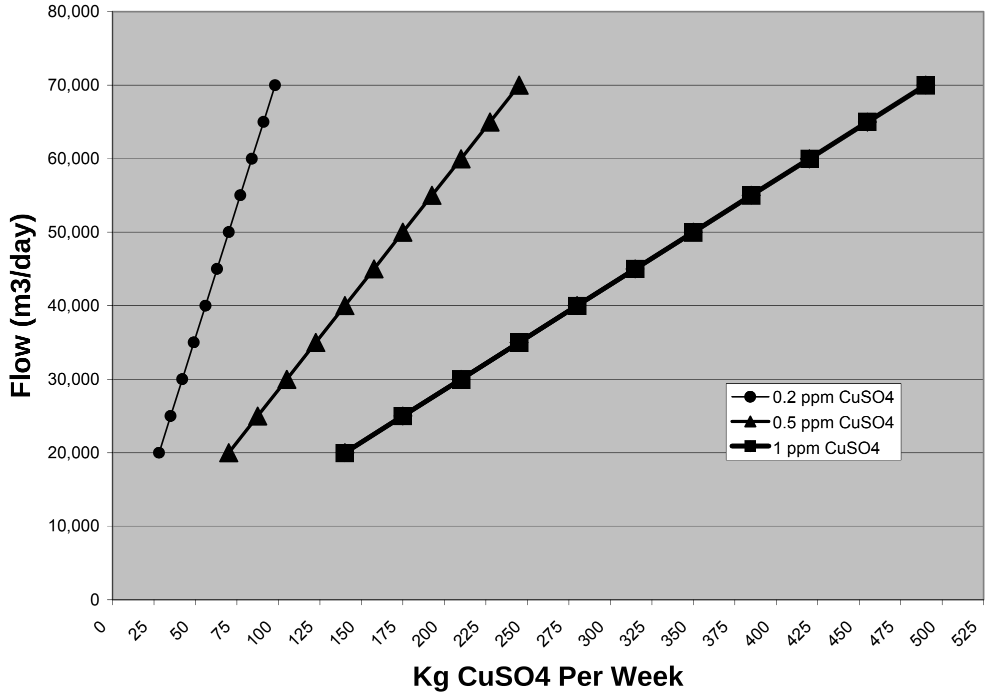
Notes for Table 4:
(1):Make all applications as **EARLY IN THE MORNING** as possible when flow is slowest. Assume flow = 30,000 m^3/day
(2):H=Head of canal; K1 = Karaoun 1 Pump Station; K2 = Karaoun 2 Pump Station; JJ = Joub Jannine Flow Regulator
(3):Make All applications **DOWNSTREAM** of the pump intake
(4):Apply copper sulfate to water slowly and evenly to maximize distribution in the canal and minimize settling to canal bottom. If algae presence is below tolerable levels, decrease application frequency or target concentration. Conversely, if algae presence exceeds tolerable levels, increase frequency or target concentration until algae is below tolerable levels.
(5) Measurements with the Hydrolabs Sonde or like device: Temperature, Specific Conductivity, Dissolved Oxygen, Salinity, Total Dissolved Solids, pH, and nitrate.
(6) Measurements with Hach test strips: pH, copper, phosphate, nitrate, ammonia, and hardness.

Copper sulfate must always be applied according to label directions. Refer to **Appendix C**.

As pointed out in Note 1 above, application rates described in **Table 4** assume a flow of 30,000 cubic meters per day (m^3/day). Depending on water flow rate and algae presence, the amount of copper sulfate required for control will vary. Higher flow rates result in more water in the canal requiring treatment and conversely, lower flows result in less water that require less copper sulfate to achieve the same concentration. Refer to **Figure 31** below. As **Figure 31** illustrates, the amount of copper sulfate needed to achieve a particular target concentration depends on flow.

Note that **Figure 31** is a simplification and assumes steady flow in the canal. In reality, canal flow varies as described in **Appendix A**. Nonetheless, the dosing requirements predicted in **Figure 31** represent with reasonable accuracy the amount of copper sulfate required to achieve the desired concentration necessary to control algae.

Figure 31. Recommended Approximate Weekly Dosing Requirements for Copper Sulfate



For example, for the 1 week period 10-June to 16-June, for a flow of 30,000 m3/day and a target copper sulfate concentration of 0.5 ppm, the total amount of copper sulfate added that week is 112 Kg and would be determined by referring to **Figure 31**. The following steps are used:

1. First, read the measured canal flow on the left side of the graph (i.e., 30,000 m^3/Day);
2. Second, select the line that corresponds to the target concentration. In this case, select the 0.5 ppm line (-▲--▲--▲-). Draw a horizontal line from 30,000 m^3/Day to the 0.5 ppm line and stop;
3. Last, draw a vertical line down to determine the kilograms of copper sulfate per week. In this case, the value is between 100 and 125 Kg and can be reasonably estimated at 112 Kg.

As further pointed out in Note 1, in order to maximize the contact time of copper sulfate to algae and increase effectiveness, apply copper sulfate early in the morning when canal flow is slowest. Note also that the uptake and subsequent effectiveness of copper sulfate is highest on sunny days and therefore applications should only be done when full sunlight is expected. Do not apply copper sulfate on cloudy or overcast days.

As pointed out in Note 3, it is critical that copper sulfate is added to canal water downstream of any pump intake in order to maximize the contact time for copper sulfate to algae in the canal and to prevent unnecessarily early transfer of copper sulfate to one of the canal's reservoirs and subsequently out into a field.

As pointed out in Note 4, in order to maximize contact time and increase effectiveness, apply fine grain copper sulfate to water slowly and evenly to maximize distribution in the canal and minimize settling to the canal bottom. Do not use large, course grain material. Start and use the lowest possible concentration of copper sulfate that is effective. Do not increase the target concentration of copper sulfate until the previous target concentration is deemed ineffective.

As further pointed out in Note 4, the amount of copper sulfate required depends on the amount of algae present or predicted to be present. If algae presence is below tolerable levels, decrease application frequency or amount. Conversely, if algae presence exceeds tolerable levels, increase frequency or amount until algae is below tolerable levels.

Prediction of future algae presence is not exact. As pointed out earlier, canal water temperature increases with time. Refer to **Figure 25**. Based on water quality data gathered by DAI and LRA personnel, increases in chlorophyll concentration and temperature appears to precede observed algae counts. Refer to **Figure 26-27**. Sole reliance on temperature and/or chlorophyll data to predict increases in algae presence, however, is not recommended. This water quality data should be used in only in combination with field observations to determine potential future algae presence.

As pointed out in Notes 5 and 6, the measurement of water quality parameters should be done and subsequently used to develop trend data like that presented in **Figures 25-29**.

2.1 Health and Safety Requirements for the Use of Copper Sulfate

Copper sulfate must always be applied according to label instructions. Refer to **Appendix C**. The following is a summary of health and safety requirements that should always be followed:

1. Copper sulfate causes severe eye and skin irritation and is harmful if adsorbed through the skin or inhaled. It may cause skin sensitization reactions in certain individuals. Avoid contact with the skin, eyes, or clothing. Avoid breathing dust. Always wear the following protective clothing:
    3. Gloves
    4. Eye Protection
    5. Dust Filter
    6. Long Sleeve Shirt
2. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse.
3. IF IN EYES, flush with plenty of water. Call a physician.
4. IF ON SKIN, wash with plenty of soap and water. Get medical attention as needed.
5. IF SWALLOWED, call a physician. Drink 1 or 2 glasses of water and induce vomiting by touching the back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.

Store copper sulfate in a cool dry location and prohibit contact unless appropriate health and safety equipment is worn.

2.2 Environmental Considerations and Requirements for the Use of Copper Sulfate

Copper sulfate is toxic to fish and aquatic organisms. Do not discharge effluent containing this copper sulfate into lakes, streams, ponds, estuaries, oceans, or public water. Do not discharge effluent containing copper sulfate into sewer systems without previously notifying the sewage treatment plant authority.

Do not exceed 6 Kg Copper Sulfate per Ha per irrigation year. This is the maximum amount suggested by the European Union (EU) that can be added to soil annually for organic food production. See: http://www.ifst.org/hottop24.htm for more details.

For example, if 112 Kg of copper sulfate is added each week over the 6 month irrigation season and irrigation water is applied over 600 Ha, this results in 4.5 Kg copper sulfate/Ha which is below the suggested annual 6 Kg/Ha EU maximum. Following the application schedule described in **Table 4**, the total amount of copper sulfate required is 1286 Kg. If this amount is applied over 600 Ha, the resulting copper sulfate load is 2.14 Kg/Ha which is well below the suggested EU maximum annual amount of 6 Kg/Ha.

2.3 Application Details for the Use of Copper Sulfate

Prior to the application of copper sulfate, the applicator must do the following:

1.) Put gloves, mask and goggles on
2.) Test wind direction by tossing grass into the area
3.) Select a bridge over the canal that is upstream of the area to be treated, but downstream of a pump intake
4.) Fill a bucket with the appropriate amount of fine grained copper sulfate. Do not use large pieces or course grain material
5.) Select the side of the bridge that is places the applicator UPWIND of the application
6.) Clear the area of any personnel downwind of the application area
7.) Slowly and evenly apply the copper sulfate with a dust pan, shovel, or other like device to the water moving from side to side across the bridge
8.) Once complete, thoroughly sweep and clean the bridge to remove any spilled copper sulfate

3. Summer Activities: Operational Control

When feasible, consider decreasing flow during evening hours and increasing flow during daylight hours to decrease daytime water temperatures and increase shear stress on algae adhered to the canal banks.

4. Winter Activities: Mechanical Control

The following steps should be taken during the winter months when the canal is dry and not being used to convey irrigation water:

1. The canal bottom should be thoroughly cleaned of all soil and debris. Weed seed may be present in canal cracks and joints and should be removed using pressure washing equipment or other suitable device
2. Retaining walls should be constructed at bridge abutments to prevent soil from entering the canal.
3. Ground on the side of the canal should be graded away from the canal so that during rain events no soil is washed into the canal.
4. Residents adjacent to the canal should be instructed on how to prevent soil from entering the canal from their property. Further, they should not be allowed to house animals close to the canal to prevent nutrients and bacteria in animal waste from

entering the canal.

5. Cost Estimation

5.1 Summer Activities: Chemical Control

Given the estimated copper sulfate use illustrated in **Table 4** and the estimated unit cost of copper sulfate of $3 USD/Kg, the cost to implement the control of algae in the canal is estimated at $3/Kg x 1286 Kg = $3,858.

Estimated labor costs for past manual control of algae were based on 10 men at a rate of $10 USD/day/man. This equates to a cost of approximately $15,000 USD for the 5 month irrigation season. Labor costs, however, are expected to less than this value when copper sulfate is used. Nonetheless, the need, if any, of continued manual removal of algae in conjunction with the use of coppers sulfate is not known and depends on the degree of control achieved with copper sulfate.

Therefore, a conservative estimate for the cost of implementing chemical control in the summer is $3,858 + $15,000 = $18,858 USD.

5.2 Summer Activities: Operational Control

Additional staff time will be required to execute changes in the operation of the canal to aid in the control of algae. The level of effort is not known.

5.3 Winter Activities: Mechanical Control

Additional staff time will be required to perform these tasks. Assuming 10 men at a rate of $10 USD/day/man for a 2 month mechanical control program, this equates to a cost of approximately $6,000 USD. In addition, the equipment such as skip loaders ($150/day) and backhoes ($150/day) will be required at a cost of $18,000 for the same 2 month period.

Therefore, a conservative estimate for the cost of implementing winter mechanical control is $6,000 + $18,000 = $24,000 USD.

This cost does not include the cost to design and build retaining walls around bridge abutments and footings. The cost for this work will vary and depend on the length, size and type of structure that is selected.

Example Copper Sulfate Label (typical)

TRIANGLE BRAND COPPER SULFATE CRYSTAL

Not for medicinal use

ACTIVE INGREDIENT:

Copper sulfate pentahydrate*	99.0%
INERT INGREDIENTS:	1.0%
TOTAL	100.0%

*Metallic copper equivalent 25.2%

KEEP OUT OF REACH OF CHILDREN

DANGER/PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

Information for Right-to-Know States:

Copper sulfate pentahydrate/CAS Reg. No. 7758-99-8: sulfuric acid, copper (2+) salt (1:1)/ CAS Reg. No. 7758-98-7; Water/CAS Reg. No. 7732-18-5

STATEMENT OF PRACTICAL TREATMENT

IF SWALLOWED: Drink promptly a large quantity of milk, egg white, gelatin solution, or if these are not available, large quantities of water. Avoid alcohol. Do not give anything by mouth to an unconscious person.

NOTE TO PHYSICIAN: Probable mucosal damage may contraindicate the use of gastric lavage. Measures against circulatory shock, respiratory depression and convulsions may be needed.

IF IN EYES: Immediately flush eyes with plenty of water for at least 15 minutes and get medical attention.

IF ON SKIN: Remove contaminated clothes and shoes; immediately wash skin with soap and plenty of water and get medical attention.

See side panel for additional precautionary statements.

EPA Reg. No. 1278-8

EPA Est. No. 1278-TX-1

Manufactured by
Phelps Dodge Refining Corporation
El Paso, Texas 79998

Net Weight
50 Lbs./22.68 Kg.

PRECAUTIONARY STATEMENTS
DANGER
HAZARDS TO HUMANS AND DOMESTIC ANIMALS

Causes severe eye and skin irritation. Harmful if swallowed or absorbed through the skin. Avoid breathing mist or dust and contact with skin, eyes, or clothing. Causes substantial but temporary eye injury. May cause skin sensitization reactions in certain individuals.

PERSONAL PROTECTIVE EQUIPMENT

Applicators and other handlers must wear long-sleeved shirt and long pants, waterproof gloves, shoes plus socks, and protective eyewear. Discard clothing and other absorbent materials that have been drenched or heavily contaminated with product's concentrate. Do not reuse them. Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

USER SAFETY RECOMMENDATIONS

Users should wash hands before eating, drinking, chewing gum, using tobacco or using the toilet. Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to fish and aquatic organisms. For terrestrial uses, do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Drift and runoff from treated areas may be hazardous to fish and aquatic organisms in adjacent sites. Direct application of copper sulfate to water may cause a significant reduction in populations of aquatic invertebrates, plants, and fish. Do not treat more than one-half of lake or pond at one time to avoid depletion of oxygen levels due to decaying vegetation. Allow one to two weeks between treatments for oxygen levels to recover.

Trout and other species of fish may be killed at application rates recommended on this label, especially in soft or acid waters. However, fish toxicity generally decreases when the hardness of water increases. Do not contaminate water when disposing of equipment washwaters. Consult your State Fish and Game Agency before applying this product to public waters. Permits may be required before treating such waters.

STORAGE AND DISPOSAL
STORAGE

Do not contaminate water, food, or feed by storage or disposal. Store unused product in original container only in a cool, dry area out of reach of children and animals. If container or bag is damaged, place the container or bag in a plastic bag. Shovel any spills into plastic bags and seal with tape.

DISPOSAL

PESTICIDE DISPOSAL: Pesticide wastes are acutely hazardous. Improper disposal of pesticide, spray mixture, or rinsate is a violation of Federal law. If these wastes cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance. Open dumping is prohibited.
CONTAINER DISPOSAL: Do not reuse empty container. Completely empty container by shaking and tapping sides and bottom to loosen clinging particles. Place the pesticide into application equipment. Then dispose of container in a sanitary landfill or by incineration if allowed by State and local authorities. If burned, stay out of smoke.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.
Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your State or Tribe, consult the agency responsible for pesticide regulation.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. This Standard contains requirements for the protection of agricultural workers on farms, forest, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment(PPE) and restricted-entry interval. The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard.
Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 24 hours.
PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water, is coveralls, waterproof gloves, shoes plus socks, and protective eyewear.

NON-AGRICULTURAL USE REQUIREMENTS

The requirements in this box apply to uses of this product that are NOT within the scope of the Worker Protection Standard for agricultural pesticides (40 CFR Part 170). The WPS applies when this product is used to produce agricultural plants on farms, forests, nurseries, or greenhouses.
Protective clothing, including goggles, should be worn.

FORMULATION OF PESTICIDES

This product is suitable for use in the manufacturing of algaecides, fungicides, mildewcides, herbicides, wood preservatives, including CCA, ACA, and ACZA compounds and tanning and preserving agents for leather and hides.

It is the responsibility of formulators using this product to register all pesticidal formulations made from it with the EPA.

CONTROL OF ALGAE AND TADPOLE SHRIMP (TRIOPS LONGICAUDATUS) IN RICE FIELDS (DOMESTIC AND WILD)

Tadpole shrimp in rice fields may be effectively controlled by the prompt and proper use of Copper Sulfate Crystal. After the rice field has been flooded to a depth of 6 to 8 inches, the Copper Sulfate Crystal should be uniformly applied at a rate of 10 to 15 pounds per acre at the first sign of infestation. Following these directions carefully should keep the concentration of copper sulfate less than 10 ppm. The "Diamond" size crystals are especially graded for maximum solubility.

POTATOES (Except California)

To enhance vine-kill and suppress late blight, apply 10 lbs. per acre in 10 to 100 gallons of water (ground equipment) or in 5 to 10 gallons (aerial equipment) with Diquat at vine-kill to enhance vine desiccation and suppress late blight. Additional applications can be made with Diquat if needed within 7 days of harvest. Triangle Brand Copper Sulfate Crystal may be applied alone until harvest to suppress late blight. NOTE: This product can be mixed with Diquat for use on potatoes in accordance with the most restrictive of label limitations and precautions. No label dosage rates should be exceeded.

SEWER TREATMENT FOR ROOT AND FUNGUS CONTROL*

Copper Sulfate Crystal is effective in keeping sewer lines free of roots.

FOR PARTIAL STOPPAGE: Add 1/2 pound of Copper Sulfate Crystal to sewer or drain and flush toward blockage with 5 gallons of water. Repeat at 6 month intervals to prevent growth of new roots.

FOR COMPLETE STOPPAGE: Physically remove the root blockage and repeat as above.

FOR HOUSEHOLD SEWERS: Use 2 to 6 lbs. Copper Sulfate Small Crystal twice yearly in spring and early fall. Apply in toilet bowl near sewer line. Flush 1/2 lb. portions at a time. Or, remove the clean-out plug and pour entire quantity directly into sewer line and flush with water. **Do not use in septic tank systems.**

FOR COMMERCIAL, INSTITUTIONAL AND MUNICIPAL USE

SEWERS: Use 2 lbs. of Copper Sulfate Small Crystal each 6 to 12 months, applied to each junction or terminal manhole.

STORM DRAINS: Use 2 lbs. of Copper Sulfate Small Crystal per drain per year. Apply during period of light flow. In dry weather, induce a flow with hose. If storm drains become almost plugged, repeat treatment 3 or 4 times at two week intervals.

SEWER PUMPS AND FORCE MAINS: Place 2 lbs. of Copper Sulfate Small Crystal in a cloth bag at the storage wall inlet. Repeat as needed.

***State laws prohibit the use of this product in sewage systems in Connecticut and in the following nine counties in California: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma.**

CONTROLLING WEEDS, ALGAE, AND MICROSCOPIC ORGANISMS IN IMPOUNDED WATERS, LAKES, PONDS, AND RESERVOIRS

It is a violation of New York State Law for anyone to apply this product to surface waters unless he is either privately or commercially certified in category 5 (aquatic), or possesses a purchase permit for the specific application proposed.

PRECAUTION CONCERNING FISH: The treatment of algae with Copper Sulfate Crystal can result in oxygen loss in the water from decomposition of dead algae. This can cause the fish to suffocate. Care should be taken when water temperature exceeds 85°F. At this water temperature, aquatic plants treated with copper sulfate decompose rapidly causing an increase in oxygen depletion. Therefore, to minimize this hazard, treat 1/3 to 1/2 of the water area in a single operation. Wait 7 to 14 days between treatments. Begin treatments along the shore and proceed outwards in bands to allow fish to move into untreated water.

APPLICATION BY DRAGGING COPPER SULFATE CRYSTAL UNDER WATER: Large or small sized Copper Sulfate Crystal is placed in burlap bags or baskets and dragged through the water by means of a boat. Begin treatment along the shoreline and proceed outward until 1/3 to 1/2 of the total area has been treated. The path of the boat should insure a distribution that is even. In large lakes, the boat should move in parallel lines about 60 feet apart. Continue dragging until all of the weighed Copper Sulfate Crystal is dissolved.

APPLICATION BY SPRAYING COPPER SULFATE SOLUTION ON WATER SURFACE: A solution can be made with Copper Sulfate Powder or Fine Crystal which dissolve easily in water. This solution can then be sprayed on the pond or lake surface from a boat. When using this method, the wind direction is important as well as the operation of the boat. Do not endanger people or animals in the boat with the copper sulfate spray.

APPLICATION BY INJECTING COPPER SULFATE SOLUTION IN WATER: A solution can be made with Copper Sulfate Powder or Crystal. This solution can then be injected into the water via a piping system.

APPLICATION BY BROADCASTING DRY COPPER SULFATE CRYSTAL: Crystals may be broadcast directly on the water surface from the shore or from a properly equipped boat. Triangle Brand Crystals ranging from ±10 mesh to ±1/2 inch are preferred for this method of application. A specifically equipped air blower can be used to discharge these size crystals at a specific rate over the surface of the water. When using this method, the wind direction is an important factor. Do not use this method unless completely familiar with this type of application.

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APPLICATION BY SPRAYING DRY COPPER SULFATE CRYSTAL FROM AIRPLANES AND HELICOPTERS: Professional personnel licensed by the State Agricultural Extension Service are allowed to apply Copper Sulfate Crystal in some states.

If treated water is to be used as a source of potable water, the metallic residual must not exceed 1 ppm copper. This equals 10.64 pounds per acre foot of water or 4 ppm of this product.

HOW TO FIND THE POUNDS OF COPPER SULFATE TO ADD TO WATER

To find acre-feet of water in a body of water, measure the body of water in feet. Calculate the surface area in square feet, divided by 43,560 (sq. ft./acre) times the average depth in feet.

1 acre-foot of water = Water measuring 208.7 ft. long by 208.7 ft. wide by 1 ft. deep.
1 acre-foot of water = 43,560 cubic feet of water.
1 cubic foot of water = 62.4 pounds.
1 acre-foot of water = (43,560)(62.4) = 2,720,000 pounds.

COPPER SULFATE PENTAHYDRATE IN WATER

POUNDS OF COPPER SULFATE CRYSTAL PER ACRE-FOOT OF WATER	=	PARTS (BY WEIGHT) COPPER SULFATE CRYSTAL PER MILLION PARTS (BY WEIGHT) OF WATER	=	PARTS (BY WEIGHT) COPPER PER MILLION PARTS (BY WEIGHT) OF WATER
0.67#/acre-foot	=	1/4 ppm	=	0.0625 ppm
1.3#/acre-foot	=	1/2 ppm	=	0.125 ppm
2.6#/acre-foot	=	1 ppm	=	0.25 ppm
5.32#/acre-foot	=	2 ppm	=	0.50 ppm

TREATMENT OF SOME ALGAE WITH COPPER SULFATE CRYSTAL

Dosage is in ppm of Copper Sulfate Crystal. A higher concentration is required if the water is hard. Consult with the State Fish and Game Agency before applying product in municipal waters.

0.25 to 0.50 ppm	0.50 to 1.00 ppm	1.00 to 1.50 ppm	1.50 to 2 ppm
	CYANOPHYCEAE ORGANISM (BLUE GREEN)		
Anabaena	Cylindrospermum	Nostoc	Calothrix
Anacystis	Oscillatoria	Phormidium	Symploca
Aphanizomenon	Plectonema		
Gloeotrichia			
Gomphosphaeria			
Polycystis			
Rivularia			
	CHLOROPHYCEAE ORGANISM (GREEN)		
Closterium	Botryococcus	Chlorella	Ankistrodemus
Hydrodictyon	Cladophora	Crucigenia	Chara*
Spirogyra	Coelastrum	Desmidium*	Nitella*
Ulothrix	Draparnaldia	Golenkinia	Scenedesmus
	Enteromorpha	Oocystis	
	Gloeocystis	Palmella	
	Microspora	Pithophora*	
	Tribonema	Staurastrum	
	Zygnema	Tetraedron	
	DIATOMACEAE ORGANISM (DIATOMS)		
Asterionella	Gomphonema	Achnanthes	
Fragilaria	Nitzschia	Cymbella	
Melorias*	Stephanodiscus	Neidium	
Navicula	Synedra		
	Tabellaria		
	PROTOZOA ORGANISM (FLAGELLATES)		
Dinobryon	Ceratium	Chlamydomonas	Eudorina*
Synura	Cryptomonas	Hawmatococcus*	Pandorina*
Uroglena*	Euglena	Peridinium	
	Glenodinium		
	Mallomonas		

*Not for use in California.

CONTROL OF WEEDS AND ALGAE IN FLOWING WATER

Potamogeton pondweeds, leafy and sago, in irrigation conveyance systems: Use the continuous application method, selecting proper equipment to supply Copper Sulfate Crystal at 0.25 to 0.5 pounds per hour for each cubic foot per second of flow for 12 hours of each 24 hours. For best control, begin copper sulfate additions when water is first turned into system to be treated and continue throughout the irrigation season. Copper Sulfate Crystal becomes less effective for mature plants. Copper Sulfate Crystal becomes less effective as the bicarbonate alkalinity increases and is substantially reduced above 150 ppm as $CaCO_3$. Mechanical or other means may then be required to remove excess growth.

Algae (such as filamentous green, pigmented flagellates, diatoms) in irrigation conveyance systems: Begin continuous addition when water is first turned on, using suitable equipment to uniformly deliver 0.1 to 0.2 pounds of Copper Sulfate Crystal per hour per cubic foot per second of flow for 12 of each 24 hours. (Note: Copper Sulfate Crystal comes in several "free flowing" crystal sizes but should be selected to match requirements of your feeder.)

Algae and weeds in irrigation systems by "slug" method of addition: Make a dump of Copper Sulfate Crystal into the irrigation ditch or lateral at 1/2 to 2 pounds per second of water per treatment. Repeat about every 2 weeks as needed. A dump is usually necessary every 5 to 30 miles depending on water hardness, alkalinity and algae concentration.

CONTROL OF ALGAE AND BACTERIAL ODOR IN SEWAGE LAGOONS AND PITS **(Except California)**

Application rates may vary depending on amounts of organic matter in effluent stream or retention ponds. Use 2 lbs. of Copper Sulfate Crystal in 60,000 gals. (8,000 cu. ft.) of effluent to yield 1 ppm of dissolved copper. Dosage levels may vary depending upon organic load.

Other Organic Sludges: Copper Sulfate Crystal solution must be thoroughly mixed with sludge. Dissolve 2 lbs. in 1-2 gals. of water and apply to each 30,000 gals. of sludge.

Useful formulas for calculating water volume and flow rates: Multiply the water volume in cu. ft. times 7.5 to obtain gallons.

Note: 1 C.F.S./Hr. = 27,000 Gals.
1 Acre Foot = 326,000 Gals.

NOTICE TO BUYER

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

DOT Hazard Class
RQ, Environmentally Hazardous Substances,
Solid, n.o.s. (Cupric Sulfate) 9, UN 3077, III

Revised 6/99

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NOTES TO THE FILE

June 14, 1999: Revised "slug" application method by Notification.